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### GREETING:

Notwithstanding the great importance [illegible] of electrochemistry have assumed in the United States and the valuable contributions which here have been made to the science and to the art, this vigorous and rapidly expanding branch of national industry has thus far lacked a [illegible] exponent. That a field exists in this country for a journal devoted specifically to the science and application of electrochemistry appears to be clearly indicated by the fact that many others, that no less than six such periodicals are published abroad, namely, three in Germany, two in France and one in England. To supply this vacancy will be the object of ELECTROCHEMICAL INDUSTRY, and it confidently hopes to be accorded in its endeavors the co-operation of all interested in the advancement of the science and the art.

It is the purpose to make this journal an authoritative exponent of electrochemical science and its various applications, and to this end the aid will be secured, so far as possible, of the leading authorities of the world in electrochemistry. In accordance with the fruitful policy of the best class of American technical journalism, the plan of the publication is to cover the field so broadly that its pages will satisfy in the most complete manner possible the needs of all interested, whether in the science or in the art of electrochemistry. Unhampered by precedent in its specific field, it will be conducted along the most advanced lines of modern technical journalism, while at the same time adhering to the [illegible] traditions which have given such an enviable character to the higher class of the American technical press.

Owing to the considerable space allotted to [illegible] chemical industries of Niagara in view of the [illegible] there of the American Electrochemical Society, [illegible] is somewhat circumscribed in the scope of [illegible]. Among the distinctive features represented, [illegible] call attention to the value of the review of the electrochemical periodical literature of the world, the analysis of current electrochemical patents, the first section of a digest of United States patents relating to electrochemistry which hereafter will appear in larger installments, and the first of a series of articles treating from the standpoint of practice the chemical and electrical principles upon which electrochemical applications are based. We are happy to announce that [illegible] leading electrochemical authorities of the world are represented to become regular editorial collaborators and each issue will contain an article from the pen of one of these. With the sincere desire that our columns may be worthy of the great industry they represent, we earnestly solicit [illegible] readers where they may further the value of the journal to art and the science; and we beg their indulgence where they may find us lacking, for any shortcoming will not be from want of devotion to the cause in which these pages are [illegible]

## THE NIAGARA MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The second general meeting of the American Electrochemical Society will be held at Niagara Falls from September 15th to 18th. While the Society is now only five months old, it has passed its infancy and has met with a success far beyond the fondest hopes of its most enthusiastic promoters. The inaugural meeting at Philadelphia will long be remembered by all who attended it; there was an unbounded enthusiasm displayed by all then present, there was a great variety of good papers, and for the first time in the United States electrochemical engineers and electrochemists came in close contact with each other. But however great the success of the Philadelphia meeting, the gathering at Niagara bids fair to be even more successful. The beauties of the Falls are ever fresh, and to the electrochemist Niagara reveals still other charms; for the first time several of the large plants of this principal center of the electrochemical industries of the world will open the doors of their workshops to the public. The programme shows again a large variety of papers on important and interesting subjects, and the presence of German and British electrochemists gives an international flavor to the whole affair. We think that the meeting will turn out a success stimulating alike to the young society and to the interests which it so splendidly represents.

## HYDRO-ELECTRIC POWER AND THE ELECTROCHEMICAL INDUSTRIES.

Perhaps the fullest statistical data on the electrochemical industries thus far published are given in a paper read by Dr. W. Borchers before the German Electrochemical Society in 1899. The capacity of all electrochemical plants of all the world at that time is given at 421,220 horse-power, of which 378,350 horse-power, or 90 per cent., is obtained from water-power. Though somewhat stale with reference to such a swiftly advancing industry, these figures nevertheless serve to emphasize a fact brought out in Dr. Richards' valuable article and in the interesting communication by Mr. W. McA. Johnson, published in this issue, namely, that the electrochemical industries have been enabled to make such remarkably rapid progress in recent years through the availability of cheap electric energy generating from water-power. The development of industrial Niagara Falls is an object lesson in this respect.

The development of large water-powers for electrical purposes was first undertaken with a view to the transmission of the energy over considerable distances, and to reduce the line loss, which increases with the square of the current, the use of relatively low currents was involved or, in other words, the employment of high voltages. Thus for a time hydro-electric power development was associated with high voltages and low current. Somewhat unexpectedly, however, and particularly at Niagara, electrochemical industries began to develop in the immediate vicinity of water power generating plants, and then diametrically opposite requirement demanded fulfillment, namely, low voltages and large currents. The heat generated in a furnace increases with the square of the current, and in electrolytic work the output in a given time is directly proportional to the current used. Therefore, for both furnace and electrolytic work, it is obviously necessary to use as large a current as possible. But the lower the voltage the less the power, which has given rise to the saying that in electrochemistry it is the volts that cost money and the ampères which bring money. While thus electrical engineering in long-distance transmission is essentially high-tension work, it is large-current work in electrochemistry. Special and peculiar engineering problems had to be solved in order to meet the requirements of electrochemical work, and in this connection we direct attention to the admirable article on transformers for electrochemical work, which we publish in this issue, from the pen of Mr. John S. Peck, the transformer designer of the Westinghouse Co.

The inherent engineering difficulties having been successfully overcome, it is but natural that the development of hydro-electric power stations should be rapid. There is every promise of even a greater rate in the future, and the development of electrochemical industries will unquestionably proceed at the same pace; for generating stations are anxious to obtain a uniform, continuous load, and to this end they cannot have better customers than electrochemical industries. Another consideration which will aid and accelerate the progress of industrial electrochemistry in this country is the abundance of valuable ores and minerals in the United States, and the relatively high value of the products to be obtained from the same. Dr. Borchers' statistics bear out this point very well. While the power available in electrochemical plants in this country in 1899 was 86,350 horse-power, or 20 per cent. of the total 421,220 horse-power of all the electrochemical plants of the world, yet the value of the products which can be produced by the 86,350 horse-power developed here per year is $97,500,000, and the corresponding value of the products which can be produced in all the electrochemical plants of the world together is $146,500,000; in other words, in these data the presumptive value of the output of the United States is 67 per cent. of that of the whole world. Richly endowed by nature, there can be no doubt that the United States will be the country par excellence of electrochemical industries. People have long enjoyed our beautiful mountains and waterfalls for aesthetic reasons. The electrochemist takes a deeper view; he thinks of the ores in the mountains and of the power in the waterfalls. He feels that here lies dormant the strength and the future of the electrochemical industry. In this sense the view of the Falls of Niagara on the front cover of the first issue of the first American electrochemical journal may be considered as symbolic.

## THEORY OF CONCENTRATION CELLS.

The paper on a "Novel Concentration Cell," read by Prof. H. S. Carhart at the Philadelphia meeting of the American Electrochemical Society, was bound to arouse general interest and animated discussion for two reasons: first, certain facts ascertained with his nickel cell apparently overthrow a theory of concentration cells which has been regarded as being well established, and which has, indeed, been looked upon as one of the most prominent achievements of the modern theory of solutions; second, Prof. Carhart not only attempts to refute an old theory, but gives at the same time the foundations of a new one. We are glad to publish in this issue some further results, obtained more recently by Prof. Carhart, and we may await with interest his paper to be read at the coming Niagara Falls

meeting of the American Electrochemical Society. Meanwhile, it may be of interest to give a concise review of the development of the theory of galvanic cells in general and concentration cells in particular, and to point out that which is new in Carhart's theory and to show its relation to older theories.

When, more than fifty years ago, Helmholtz published his famous paper on the conservation of energy, he made a brief attempt to give a theory of the galvanic cell, under the assumption that the total chemical energy disappearing during electrochemical action is changed into electrical energy; this gives at once a simple relation between the e. m. f. of a cell and the formation heat of the chemical processes in it. Wm. Thomson (now Lord Kelvin) studied this matter shortly afterward, in greater detail, and since then it has become the custom to call that simple relation Thomson's rule. It was found, however, later that the fundamental supposition upon which this rule is based, is not quite correct. In electrochemical actions we have not simply a change of electric energy into chemical energy and *vice versa*, but heat also takes part in the process. By applying the two principles of thermodynamics to the problem, it was found that a correction factor, due to the heat effect, had to be added to the Thomson rule; the modified rule is now generally called the Gibbs-Helmholtz equation.

In the meantime the attention of some investigators had been directed to the study of a special and very simple type of cell, namely, what we now call a concentration cell, *i. e.*, a cell in which the total change of chemical or internal energy corresponds to a change of concentrations. Helmholtz was again the first who in 1877 attacked this problem on the basis of the principles of thermodynamics. He devised an ingenious reversible isothermic cycle in which the concentration cell is first discharged and then the concentration changes are made retrograde by means of isothermic distillation; by applying the principles of thermodynamics to the cycle, he found a relation by which the e. m. f. of a concentration cell can be calculated if the aqueous vapor pressure over the electrolyte is known as a function of the concentration of the electrolyte. A bold step forward was then made by Nernst in 1889. At first glance Nernst's theory appears to be something entirely new, but a more careful analysis soon reveals the fact that he uses the two principles of thermodynamics just in the same way as Helmholtz did, but while he does so, he also makes use of the very distinct assumptions of the electrolytic dissociation theory concerning the constitution of an aqueous solution, and also of some additional ingenious assumptions concerning the so-called solution tension at a reversible electrode. The results which Nernst obtained in this way are in general accord with Helmholtz's theory—naturally because they are based upon the same broad principles—but as Nernst uses suppositions of his own, his results go further; he obtains a very distinct mechanical illustration or model of what happens in a concentration cell, and he can then apply his results to galvanic cells in general. He localizes the sources of e. m. f. at the electrodes and the junctions of different concentrations or different electrolytes, and he resolves the whole electrochemical action in a galvanic cell into a mechanism of ions. His theory of concentration cells has been confirmed repeatedly by measurements, until Prof. Carhart described his nickel cell, which seems to contradict Nernst's theory.

To understand and appreciate the recent work of Prof. Carhart, it is necessary to refer to an important paper published by him in 1900 in the *Physical Review*. Prof. Carhart starts from the correct idea that the Gibbs-Helmholtz equation represents our most assured and best-established knowledge of the relation between the electric, thermic and chemical quantities in an electrochemical system; he starts from this equation and makes an important step to elaborate it. Heat is either taken in or given out by the system, or both occur at the same time at different points of the system. This is the object of Prof. Carhart's investigations. He localizes the heat effect at the two electrodes and separates them; thus instead of one temperature coefficient of the e. m. f. in the Gibbs Helmholtz equation, he gets a sum of two, referring to the two electrodes. This is evidently a step in the right direction; he accomplishes the result that at least part of the total action is localized; while Nernst obtains the same result to a far greater degree by theoretical speculations, Carhart does it by experiment. Prof. Carhart's modification of the Gibbs-Helmholtz equation is valid for any galvanic cell; but it can evidently be best tested by a concentration cell with very dilute solutions; for the change of internal chemical energy, corresponding to concentration changes in very dilute solutions, is practically zero, hence in such a concentration cell we have practically an exchange only of electrical and heat energies. This consideration has evidently led Prof. Carhart to take up the study of concentration cells. He has built up his nickel cell exactly as concentration cells are generally built up; he has two nickel electrodes in two solutions of nickel sulphate of different concentrations. This does not prove, however, that this is really a concentration cell in the sense of Nernst's theory. Nernst in developing his formula, assumes that in a concentration cell of this type, the metal goes into solution at the anode and is deposited upon the cathode. In the experiments published by Carhart there is nothing to prove that this really takes place in his nickel cell; indeed, we have good reasons to doubt it in view of the established fact that during discharge the current in the nickel cell flows from the concentrated to the dilute solution. For we would be led to the conclusion that during discharge the dilute solution becomes more dilute and the concentrated solution becomes more concentrated, and this would be in contradiction with the second principle of thermodynamics, which is used by Prof. Carhart himself for establishing his theory. Hence it is quite probable that the chemical action at the electrodes in the nickel cell is somewhat different; it may be that chemical energy is here changed into other forms of energy; then we would not be justified to call it a concentration cell, and there would be no contradiction with Nernst's theory. While the sensational disagreement with Nernst's theory would then disappear, the general important value of Carhart's work, as sketched above, would not be diminished. There is no doubt that by Prof. Carhart's general formula we will be enabled to get a deeper knowledge of what happens in a galvanic cell, without making any doubtful hypothesis, but simply by experimental work. The very interesting results obtained by Prof. Carhart with the Daniell cell are alone sufficient to prove the value of his theory.

## THE AMERICAN ELECTROCHEMICAL SOCIETY.

The American Electrochemical Society will hold its second general meeting at Niagara Falls, September 15, 16, 17, 18, 1902. The meetings will be devoted to the reading of papers, and the afternoons and evenings to visits and social meetings.

Members and guests will register and receive their badges as soon after their arrival as possible. Badges will be given to all members in good standing and to applicants who have deposited their formation fee. Special badges will be provided for guests, who must be introduced by a member.

*Monday morning, September 15th, at 9 A. M.*

Meeting of Board of Directors at International Hotel.

*Monday morning, September 15th, at 10 A. M., in the music room of the International Hotel.*

Reading and discussion of the following papers:

Francis A. J. Fitzgerald, Niagara Falls, N. Y.: "Note on Testing Carbon Electrodes."

Prof. J. W. Richards, Ph.D., Lehigh University, Bethlehem, Pa.: "Efficiency of Electric Furnace Operations."

P. G. Salom, Philadelphia, Pa.: "Additional Notes on Lead Reduction."

Alfred T. Weightman, Niagara Falls, N. Y.: "Cathodic Reduction."

Prof. Louis Kahlenberg, Ph.D., University of Wisconsin, Madison, Wis.: "Differences of Potential between Metallic Cadmium and Solutions of Cadmium Iodide in Various Solvents."

*Monday afternoon, September 15th, at 2.30 P. M.*

Inspection of power house of Niagara Falls Power Co. and visits to electrochemical works, to be arranged by the Local Committee, starting from the International Hotel.

*Monday evening, September 15th, at 7 P. M.*

Reception in the parlors of the International Hotel. A Ladies' Committee will co-operate.

8 P. M. Banquet for members and ladies, followed by a ball at the International Hotel.

*Tuesday morning, September 16th, at 9.30 A. M., in the Auditorium of Natural Food Co's Building.*

Reading and discussion of the following papers:

Prof. R. S. Hutton, Owens College, Manchester, Eng.: "The Fusion of Quartz in the Electric Furnace."

Marcus Ruthenberg, Philadelphia, Pa.: "Developments in Electrometallurgy of Iron and Steel."

Prof. H. T. Barnes, Ph.D., McGill University, Montreal, Can.: "Theory and Practice of Continuous Flow Calorimetry."

Carl Hering, Philadelphia, Pa.: "An Apparent Electrochemical Paradox."

C. J. Reed, Philadelphia, Pa.: "Some Phenomena of Electrolytic Conduction."

Prof. Henry S. Carhart, LL.D., University of Michigan, Ann Arbor, Mich.: "The Nickel Concentration Cell."

Prof. W. F. Goldsborough, Lafayette, Ind.: "Electrochemistry at the World's Fair, St. Louis."

*Tuesday afternoon, September 16th, at 2.30 P. M.*

Visits to works and places of interest, to be arranged by the Local Committees, starting from the International Hotel.

*Tuesday evening, September 16th.*

Special search light trip on the Niagara Gorge Railway.

*Wednesday morning, September 17th, at 9.30 A. M., in the music room of the International Hotel.*

Reading and discussion of the following papers:

Axel Reuterdahl, Providence, R. I.: "The Electronic Hypothesis and Its Applications."

Prof. John Langley, Ph.D., Cleveland, Ohio.: "Electrochemical Polarization."

Hugh Rodman, Philadelphia, Pa.: "Storage Battery Invention."

Woolsey McA. Johnson, New Brighton, S. I., N. Y.: "The Electrolytic Dissolution of Soluble Metallic Anodes."

C. W. Volney, Ph.D., Keyport, N. J.: "On the Electrolysis of Sodium Nitrate and the Composition of the Developed Gases."

*Wednesday afternoon, September 17th, at 2.30 P. M.*

Excursion and picnic to Dufferin Islands in Queen Victoria Park. The house and grounds of the Niagara Falls Country Club will be open to members for golf, tennis, etc., and may be reached by trolley from the hotel.

*Thursday morning, September 18th, at 9.30 A. M.*

Reading and discussion of the following papers:

D. H. Browne, Cleveland, Ohio: "Pumps and other Accessories in Electrolytic Plants."

Prof. G. B. Frankforter, University of Minnesota, Minneapolis, Minn.: Subject to be announced.

Titus Ulke, Sault Ste. Marie, Ont., Can.: Subject to be announced.

Several other papers are expected.

*Thursday afternoon, September 18th.*

Private visits to electrochemical plants by personal invitations.

After the above programme had been issued, the following three additional papers were announced:

Alfred H. Cowles, Cleveland, Ohio: "A Unit of Quantity of Electricity for Use in Electrochemical Calculations."

Edw. R. Taylor, Penn Yan, N. Y.: "Some Further Advances on the Closed and Continuous-working Electric Furnace."

Prof. F. Haber, Ph. D., Karlsruhe, Germany: Subject to be announced.

Visits will be arranged to a number of the installations of special interest to electrochemists, as also to places of general interest. Badges will be necessary to entitle members and guests to the privilege of taking part in the visits and excursions.

## PROPOSED BRITISH SOCIETY OF ELECTROCHEMISTS.

For some time past it has been thought to be advisable to form an electrochemical society in Great Britain.

An informal meeting to discuss the subject was held on March 4, 1902, at which a committee consisting of the following gentlemen was chosen to consider the subject: J. Swinburne (the present president of the British Institution of Electrical Engineers), Dr. F. M. Perkin, Dr. Donnan, W. R. Cooper, S. Cowper-Coles and H. V. Simpson. This committee has held meetings from time to time at which the best methods of procedure have been carefully discussed. The question of working in conjunction with one of the existing societies has also been considered, and several societies have been approached on the matter, but the committee takes the view that such an arrangement is not likely, at any rate, for the present, to have the desired effect. They have come to the conclusion, therefore, that the society should be independent. Steps in the direction of organizing this society have just been taken.

It has been suggested that there be two classes of members: full members and associate members, the subscription fee being two guineas and one guinea respectively. (*i. e.*, about $10 and $5).

The honorable secretary of the committee is H. V. Simpson, Grosvenor Mansion, Victoria street, S. W., London, Eng.

We hope the society will be founded and will meet with great success.

## TRANSFORMERS FOR ELECTROCHEMICAL WORK.

By J. S. Peck.

IN electrochemical work the demand is ordinarily for a transformer capable of delivering extremely heavy secondary currents at widely varying voltages, and which shall have a construction sufficiently rugged to stand excessive overloads for short periods and to operate twenty-four hours per day without deterioration.

The transformer which has been almost universally adopted for this work is that known as the oil-insulated water-cooled type. The transformer proper is mounted in a case of boiler iron, which is filled with oil, with primary and secondary leads carried through the top of the case.

The function of the oil is to increase the insulation strength and to carry the heat from the active parts of the transformer, where it is generated, to the cooling surfaces.

Water is almost always used for cooling, but there are a number of different methods of utilizing it. Where the secondary conductors are very heavy they are sometimes made hollow and the cooling water circulated directly through the conductors. This method, while very effective in cooling the secondary winding, takes up valuable space within the transformer, gives a bulky conductor in which eddy currents may be set up and is difficult to make water tight.

Another method consists in pumping the oil from the transformer case to an elevated cooling tank, where it comes in contact with water coils, is cooled and then allowed to circulate by gravity through the transformer.

The system in most common use, however, consists in placing the water-cooling coils within the transformer case below the surface of the oil. This brings the cooling coils into intimate contact with the oil, making a most efficient method of cooling, and one requiring the minimum amount of cooling apparatus and attention.

The design of a transformer for extremely heavy currents involves a number of interesting problems, a full appreciation of which requires a considerable knowledge of electrical engineering.

When a current of electricity flows through a circuit, a magnetic field is set up; if the current is alternating, then the field alternates also and induces a voltage in the circuit opposed or counter to the impressed voltage. The effect of this counter voltage is to cause an increased drop of pressure in the circuit, so that the voltage delivered to the load may be very much less than would be obtained with direct current where the only drop is that due to ohmic resistance.

The amount of this counter voltage increases directly with the current in the circuit and with the frequency or rate of alternations. It also increases as the distance between conductors is increased, and varies somewhat with the size and shape of the conductors themselves.

In electrochemical work, where the volume of current is large and the voltage low, the conditions are favorable for the production of a high percentage of counter voltage, and unless special precautions are taken it may be, with full-load current, almost as large as the impressed voltage, leaving practically no pressure for forcing current through the load.

To reduce this counter voltage the secondary is divided into a large number of parallel circuits, placed side by side, and as near together as mechanical considerations will permit. Thus the current in any one circuit is kept down to a reasonable volume, the conductors are kept close together with a correspondingly reduced counter voltage.

Where a number of circuits are thus operated in parallel it is customary to have each circuit supplied from a separate coil in the transformer, and great care is necessary in the design of the transformer to obtain a symmetrical relation between primary and secondary windings, in order that the voltage induced in all the coils may be the same. If the voltage on the different coils is not the same, then the coil or coils having the higher voltage will force a local current through the coil or coils of lower voltage, which will result in unequal and excessive heating in the coils.

Another element of danger in the design of apparatus for heavy currents is the stray field induced by the current in the conductors. For if this field cuts the large conductors, heavy local or eddy currents may be set up. This trouble is particularly apt to occur inside the transformer, and careful consideration must be given to it when a transformer is designed.

Since the counter voltage induced in a circuit depends upon the rate of alternations, it is obviously desirable to have as low a frequency as possible. For most of the electrochemical work done up to the present time a frequency of 3,000 alternations per minute (or, in other words, 25 full periods per second) has been used, as low a value as is considered feasible for general power distribution. In certain cases, however, where extremely heavy currents at low voltage have been demanded, difficulty has been experienced in keeping down the counter voltage to anything like a reasonable value, and it is probable that for certain electrochemical work a frequency considerably lower than this will be adopted.

In electrochemical work the great majority of transformers are supplied from primary mains, the voltage of which cannot be varied, and as one of the requirements for this work is that the transformer shall deliver a variable secondary voltage, it is necessary that some means of varying the voltage be provided in connection with the transformer itself.

There are two general methods of accomplishing this variation:

1st. By changing the ratio between the primary and secondary turns.

2d. By placing in the primary or secondary circuit of the transformer an auxiliary transformer, having a variable voltage ratio, the voltage of which may be added to or subtracted from that of the main transformer.

Of the two methods the first is ordinarily the simpler and cheaper, and will be first considered.

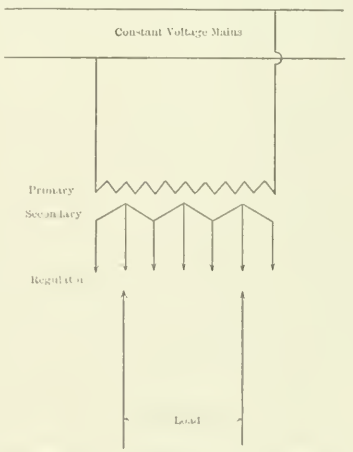



FIG. 1.—REGULATOR IN SECONDARY OF TRANSFORMER.

Fig. 1 shows diagrammatically the primary and secondary windings of a transformer. From the secondary winding a number of taps are brought out, so that by connecting to different taps a varying number of secondary turns may be obtained. If the transformer is supplied from 2,000-volt mains and there are 200 turns in the primary winding, then there will be upon every turn in the transformer 10 volts. If the secondary has 10 turns, the total voltage induced in this winding will be 100. If one of the secondary terminals be moved so

that there are but 5 turns between the two terminals, then but 50 volts will be delivered. If 8 turns are included, then 80 volts will be delivered, etc.

With large transformers there are a number of objections to this method of varying the number of secondary turns. One is that the current in the secondary is so large that it is difficult to change from tap to tap without cutting off the current from the transformer. Another is that the voltage steps obtained are usually too large a percentage of the total voltage to be permissible.

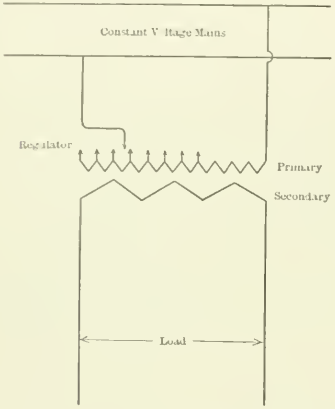



FIG. 2.—REGULATOR IN PRIMARY OF TRANSFORMER.

To avoid this difficulty a modification of this method, shown in Fig. 2, is used. Here the taps are brought out from the high tension winding and means are provided for stepping one line terminal from tap to tap.

If, as before, the primary voltage is 2,000, the primary turns 200 and the secondary turns 10, then with the whole primary winding in there will be 10 volts per turn and 100 volts on the secondary. If half the primary winding be cut out, so that there remains but 100 turns, then there will be 20 volts per turn and 200 volts on the secondary. If the primary voltage is impressed on 150 turns, there will be 13⅓ volts per turn and 133 volts on the secondary winding.

As the primary winding has many more turns than the secondary, it is possible to obtain much smaller steps than when the change in turns is made on the secondary. The primary current is small compared with the secondary, and may be usually handled without serious difficulty.

For changing the line terminal from one tap to another, a regulating dial is required. If the output of the transformer is small, so that the primary current is low and the voltage between taps not excessive, then a dial similar to that shown in Fig. 3 may be satisfactorily used. If, however, the current is very heavy or the volts between steps excessive, it is necessary to supply a more substantial type of regulator. Fig. 4 shows a switchboard type of regulator designed for handling heavy currents, with several hundred volts between steps.

The connections for this regulator are shown in Fig. 5. When switch No. 1 is closed, the line terminals are connected directly across the total winding. If it is desired to cut out turns to raise the secondary voltage, the method of procedure is as follows: switch No. 2 is closed, switch No. 1 is opened, switch No. 3 is closed and switch No. 2 is opened. When switches No. 1 and No. 2 are closed at the same time, a resistance "R" prevents a short circuit and excessive flow of current between the points 1 and 2 on the transformer winding. The same condition exists when switches No. 2 and No. 3 are closed at the same time. When switch No. 3 is connected to the line and all others open, it is evident that the line terminal X is connected directly to the transformer winding at 3, thus cutting out entirely turns between 1 and 3.

On this particular regulator the switches were operated by hand one at a time. It is, however, desirable to have the different switches actuated by a common shaft driven by a crank at the end of the board, and such an arrangement may be easily adapted to a regulator of this type. The great merit in this form of regulator is that the construction is exceedingly simple and substantial, so that there is little danger of the

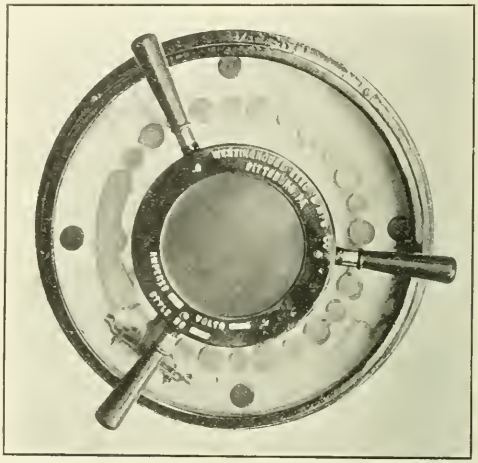


FIG. 3.—REGULATING DIAL.

troubles developing in this regulator which are common to many regulators of the dial type.

The second system of regulation, which consists in placing a regulating transformer in series with the primary or secondary of a transformer, may be operated in a number of different ways.

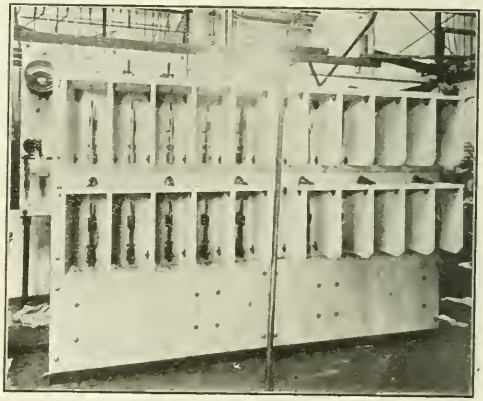


FIG. 4.—SWITCHBOARD TYPE OF REGULATOR.

Fig. 6 shows a regulating transformer placed in the secondary of the main transformer. To vary the voltage of the regulating transformer the number of turns in the secondary are changed as indicated in the diagram. When the voltage of the regulating transformer is in such a direction as to assist that of the main transformer, the voltage applied to the load will be the sum of the secondary voltage of main and regu-

lating transformer. When the voltage of the regulating transformer opposes that of the main transformer, the voltage on the load will be equal to the difference between the voltage of the main and that of the regulating transformer.

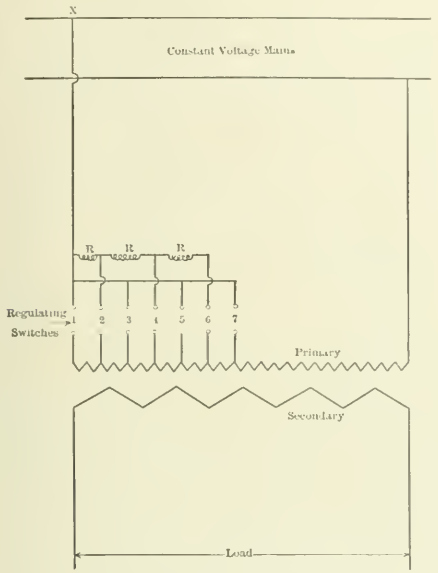



FIG. 5.—CONNECTIONS OF REGULATOR.

The objection to this particular method lies in the difficulty of handling, on any type of regulator, the heavy currents in the secondary circuit; also to the fact that the voltage steps obtainable are ordinarily larger than is permissible.

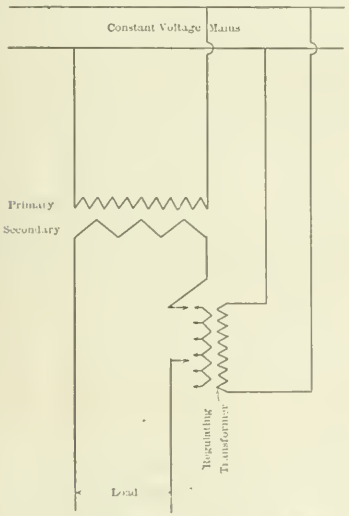



FIG. 6.—REGULATING TRANSFORMER IN THE SECONDARY OF THE MAIN TRANSFORMER.

Fig. 7 shows the same type of regulating transformer, but connected in the primary circuit. When so placed the currents to be handled are much smaller and finer adjustments in voltage may be obtained.

Fig. 8 shows a method of regulation in which the ratio of primary and secondary turns in the regulating transformer is maintained constant, the voltage being varied by changing the voltage impressed upon the primary of the regulating trans-

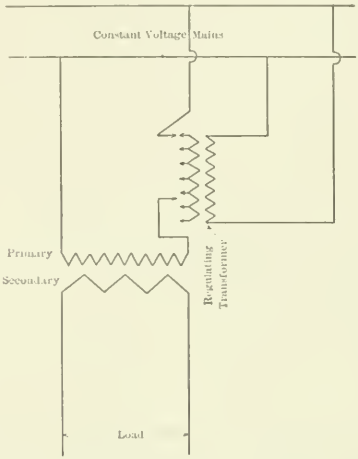



FIG. 7.—REGULATING TRANSFORMER IN THE PRIMARY OF THE MAIN TRANSFORMER.

former. The variable voltage for the regulating transformer is obtained from an auxiliary "auto" or single-coil transformer. With this scheme the current in the regulating circuit may be kept down as low as desired by choosing a suitable voltage for the primary of the regulating transformer. Fig. 8 shows the regulating transformer in the secondary circuit, but it could obviously be as well placed in the primary circuit.

Fig. 9 shows a modification of the method shown in Fig. 8. Here the primary of the regulating transformer is supplied

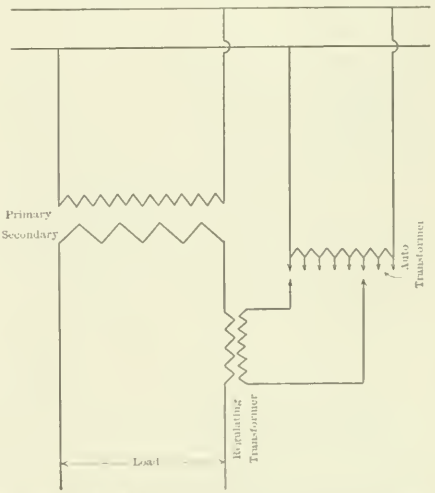



FIG. 8.—METHOD OF REGULATION BY MEANS OF A REGULATING TRANSFORMER AND AN AUXILIARY AUTO TRANSFORMER.

from taps which are brought out from the primary winding of the main transformer, thus doing away with the necessity of the auxiliary auto transformer.

In all the methods of regulation which have been described

the variation in voltage is obtained by the step-by-step method, although the main circuit of the transformer is never opened, so that current is never cut off from the load. In certain classes of electrochemical work it is necessary that the voltage be varied gradually, moving by steps. Where this is required, it is customary to place in series with the primary or secondary winding of the main transformer the secondary of an induction regulator (see Fig. 10). This regulator is a form of trans-

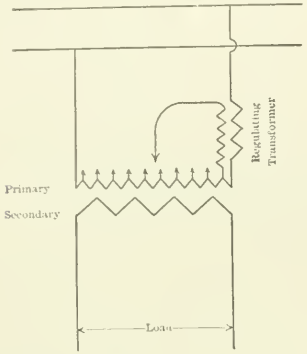



Fig. 9.—Modification of the arrangement of Fig. 8.

former so arranged that the primary and secondary windings may be moved inductively with relation to each other, so that by a proper movement the secondary voltage of the regulator can be varied from 0 to a positive or negative maximum, the change in voltage being at a perfectly uniform rate. The objection to this form of regulator is its high cost and low efficiency as compared with regulators of the step-by-step type.

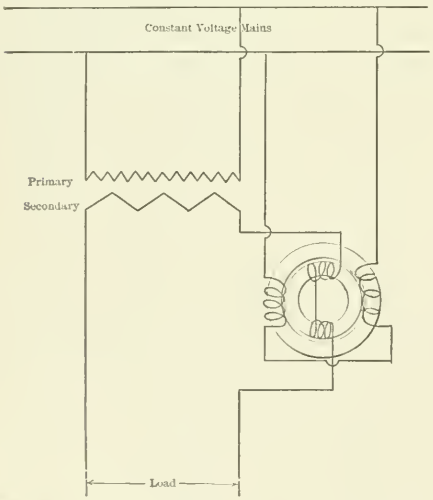



Fig. 10.—Method of regulating the voltage at a uniform rate.

To say that the construction of transformers and regulators for delivering heavy currents at variable voltages has kept pace with the growth of the electrochemical industry is sufficient to indicate the development along this line. But such is the case, and the limit to the amount of current or range in voltage will not be set by the transformer designer, but rather by commercial considerations and the demand of the electrochemical industry.

## IONIC VELOCITIES IN LIQUID AMMONIA SOLUTIONS.*

By Prof. Edward C. Franklin and Hamilton P. Cady.

Measurements of the electrical conductivity of salts dissolved in liquid ammonia have shown that such solutions carry the current with remarkable facility, surpassing in this respect even aqueous solutions themselves. As an example may be cited the case of potassium nitrate, which in solution in liquid ammonia shows the following conductivity as compared with aqueous solutions at the same concentrations:

| Dilution | Molecular Conductivity of $KNO_3$ in $NH_3$ at $-33°$ | $H_2O$ at 18° |
|---|---|---|
| 1 | ..... | 75.2 |
| 10 | 88.0 | 103.7 |
| 100 | 138.5 | 114.0 |
| 1,000 | 245.0 | 119.0 |
| 10,000 | 319.0 | 122.0 |
| 50,000 | 337.0 | 121.5 |
| 70,000 | 338.0 | ..... |

Other salts show an entirely similar behavior.

The rapid increase in the molecular conductivity with dilution and its final high value are interpreted as meaning that in the more concentrated solutions the salts are dissociated to a much smaller degree in ammonia than in water, and that to complete the dissociation in ammonia solutions the dilution must be carried much higher than is necessary in the case of aqueous solutions. Referring to the table given above, it will be seen that while dissociation is well on towards completion in water solutions at a dilution of 1,000, in ammonia solutions, on the other hand, the dilution must be carried up to somewhere between 10,000 and 50,000 in order to bring about the same degree of dissociation.

Now, if liquid ammonia solutions are to meet the requirements of the theory of electrolytic dissociation, it is necessary to assume that the ions in this solvent travel at a much greater speed than they do in aqueous solutions. It was to determine by direct measurement the velocity with which a number of anions and cations travel in liquid ammonia that the present investigation was undertaken.

The method used consisted, for example, in the case in which the velocity of a cation was to be measured, in noting the speed with which the boundary between two solutions containing a common anion traveled up a graduated tube. The solution containing the cation whose speed was to be measured was superimposed upon a solution containing a heavier and slower cation. The velocity with which the meniscus moves up the tube is conditioned only upon the faster cation, the slower, heavier cation serving merely as an indicator. The details of the somewhat complicated piece of apparatus, together with the complete data, will be published in the near future.

The results obtained are as follows, compared with the speeds of the same ions in water solutions:

| | Velocity in cm per sec per volt. in $NH_3$ at $-33°$ | in $H_2O$ at 18° |
|---|---|---|
| Ammonium | 0.00133 | 0.00055 |
| Potassium | 0.00167 | 0.00057 |
| Sodium | 0.00132 | 0.00035 |
| Silver | 0.00103 | 0.00046 |
| Nitrate ion | 0.00166 | 0.00053 |
| Bromine ion | 0.00168 | 0.00059 |

These values are in very fair agreement with the conductivity measurements of Franklin and Kraus.

* Abstract of a paper read at the Pittsburg meeting of the A. A. A. S., July, 1902.

## CONTRIBUTIONS TO THE THEORY OF CONCENTRATION CELLS.*

By Prof. Henry S. Carhart.

The two classes of simple concentration cells are:

1st. Two electrodes of the same metal immersed in a solution of a salt of this metal, the density of the solution at the two electrodes being different.

2d. Two electrodes consisting of an amalgam of the same metal, the concentration of the metal in the amalgam being different at the two electrodes, both immersed in a solution of a salt of this metal.

The usual Nernst formula for the electromotive force of a concentration cell requires that the direction of the electromotive force through the cell shall be from the dilute to the concentrated solution. Considerations derived from the thermo electromotive force at the contact of metals and their salts, led the author to construct a concentration cell of the first of the above classes in which the direction of the electromotive force within the cell is from the concentrated to the dilute solution. It consists of nickel immersed in a solution of nickel sulphate or chloride.

In the Nernst formula the electromotive force is proportional to the absolute temperature. This suggests a thermal origin for the electromotive force of a concentration cell. From this point of view *concentration cells are devices for converting the heat of their surroundings into electrical energy.*

The same conclusion is reached when one considers the Helmholtz equation for the electromotive force of a voltaic cell. It may be written

$$E = \frac{H}{q} + T\frac{dE}{dT}.$$

H is the heat equivalent of the chemical reactions. If the temperature coefficient is positive, the energy given out by the cell is greater than the chemical energy transformed, or the element tends to cool and to take heat from its surroundings. In general, as the author has shown in another paper, heat is absorbed on one side of the cell and is generated on the other side. In the Daniell cell the two almost exactly counterbalance each other.

If the Helmholtz equation is generally applicable, then where there are no chemical reactions to furnish energy, the only source of electrical energy is heat. The electromotive force is then obviously thermal. From this point of view the nickel concentration cell does not constitute an exception, save that the thermo-electromotive force is directed from the metal to the solution of its salt, while with zinc, copper, silver, cadmium, etc., it is the other way.

These facts are not sufficient to explain the electromotive force of a concentration cell without the aid of another law, which the author has discovered, namely, the law of the increase of the thermo-electromotive force with the concentration of the solution, and of its decrease with the increase of the concentration of the metallic ion in the amalgam. Hence, the thermo-electromotive forces on the two sides of the cell do not balance each other, and the residual explains the electromotive force of the concentration cell. Curves were shown exhibiting the relation between thermo-electromotive forces and concentrations, both as regards solutions and amalgams. Hence, both classes of simple concentration cells are explained by means of the thermo-electromotive forces at the contact between the electrodes and the solution.

Since the thermo-electromotive force increases with the concentration of the solution and decreases with the concentration of the ion in the amalgam, it should be possible to offset the one with the other. A single trial with zinc amalgam and zinc-sulphate solutions gave a cell with an electromotive force of only 0.0004 volt.

The law of the increase of the thermo-electromotive force with the concentration of the solution explains two well-known facts about the Daniell cell:

1st. Its electromotive force increases with the density of the copper sulphate solution and decreases with the increase in density of the zinc-sulphate solution. With these metals the thermo-electromotive force is directed from the solution to the metal. It is, therefore, clear that any increase in the concentration of the copper-sulphate solution must increase the thermal component of the electromotive force of the cell, and conversely with the zinc-sulphate solution. The only other explanation of this fact ever given is based on osmotic pressure.

2d. It is known that the temperature coefficient of the Daniell cell at ordinary concentrations is negative; that with concentrated copper sulphate, and zinc sulphate solution having a density of about 1.04, it becomes zero; with a still weaker zinc sulphate solution, the temperature coefficient is positive. This fact is readily explained when one remembers that the temperature coefficient of the cell is the resultant of all the thermo-electromotive forces at the several contacts. The one at the $Zn\text{-}ZnSO_4$ reduces the electromotive of the cell or tends to make the temperature coefficient negative. By reducing the concentration of the zinc sulphate solution this thermo electromotive force is reduced till it is smaller than that at the copper plate, and then the temperature coefficient of the cell becomes positive.

* Abstract of a paper read at the Pittsburg meeting of the A. A. A. S. July, 1902.

## ELECTROCHEMISTRY AS AN ENGINEERING COURSE.

By Prof. C. F. Burgess, E. E.

The establishment of a four years's course in applied electrochemistry finds its justification in the marked development of the electrochemical industries and the consequent demand for men having a special training. The marked differences of opinion which have been expressed as to what electrochemical training should consist in, arises from differences of opinion as to what the product should be, whether an electrochemical engineer or an electrochemist.

The industrial development of electrochemistry has been the result of adapting former and well-known laboratory experiments to large-scale industrial practice more than to new scientific discoveries, and progress along this line will undoubtedly continue. Chemical manufacturing was a number of years ago considered best developed when the processes were so simple that no power was necessary to assist in the chemical reactions, but this condition has changed and the chemical industries are now pre-eminently power-using industries. This has been the result to a large degree upon the use of electrical energy either in the electrolytic cell or the electric furnace for producing chemical changes.

A knowledge of the properties of materials of construction and of the transformations, distributions and utilization of various forms of energy is, therefore, essential for an electrochemical engineer, and such knowledge can best be obtained in an engineering course, conducted along much the same lines that are followed in electrical, mechanical, or other engineering courses.

Something over a year ago the Engineering College of the University of Wisconsin established a four years' course with the object of furnishing such training, and designed in accordance with the idea that the electrochemical engineer should be primarily an engineer, with however a considerable knowledge of chemistry and chemical engineering subjects. The principal difficulty is that a great amount of laboratory work is necessary in connection with most of the required studies, and the amount of time which should be devoted to all of them is hard to crowd into a four years' course.

* Abstract of a paper presented at the recent Pittsburg meeting of the Society for the Promotion of Engineering Education.

## PIONEERS OF ELECTROCHEMISTRY—I.

### Charles M. Hall.

CHARLES M. HALL, inventor of the Hall process for producing aluminum, was born at Thompson, Geauga County, Ohio, on December 6, 1863. His father is a Congregational minister, and moving to Oberlin in 1873, young Hall attended the public schools there and later Oberlin College. At college he took the classical course, graduating in 1885. During the course he had one term of chemical study with Professor Jewett, and was so captivated with the subject that for nearly a year thereafter he experimented in the Oberlin laboratory, with the special object of finding an electrical method of commercially producing aluminum. The detailed history of these attempts is as follows:

Hall's experiments were made with a galvanic battery as the source of his current, and a gasoline burner to heat his crucibles. His idea was that alumina was the cheapest aluminum compound, and that if he could find some easily-fusible salt which would, when molten, dissolve alumina, he might, by electrolysis, obtain from the bath aluminum and oxygen, just as copper and chlorine are obtained by electrolyzing an aqueous solution of copper chloride. His early experiments failed because of using clay crucibles, and it was not until he lined the crucibles with a mixture of ground gas-retort carbon and tar that he succeeded in producing the metal. This was on February 23, 1886. The solvent bath then used was cryolite, the double fluoride of aluminum and sodium.

Charles M. Hall

In the summer of 1886 he went to Boston, where his brother, a clergyman, raised money to continue the experiments, power was rented and four months' work done with a small dynamo. The basic patent for the process, using for the solvent bath a double fluoride salt of aluminum and of a more electropositive metal, was applied for on July 9, 1886. Much of the work at Boston was directed towards working the bath with copper anodes, which, indeed, work to some extent, by becoming oxidized superficially, but have since been proven decidedly inferior to carbon anodes. The finding of the best anodes to use in the bath consumed practically two years' time, and, meanwhile, the work at Boston was discontinued, after four months of effort.

Returning to Oberlin, in the fall of 1886, Hall stuck with dogged perseverance to his task of developing a commercial process. He constructed a large bichromate-sulphuric acid battery of 12 cells, each a gallon capacity, casting the zincs himself by melting down scrap zinc. He had no current-measuring instruments, but, working with small iron crucibles, 2 inches in diameter, carbon lined, obtained lumps of metal one-quarter ounce in weight, at a run. The work was carried on mostly with the use of potassium fluoride in the bath, instead of sodium fluoride. This bath is more easily fusible than the sodium bath, but is not so permanent, and, therefore, not so suitable for a continuous process. The results, however, were encouraging, and in December, 1886, Hall went to Cleveland, where an uncle resided, in order to raise funds to work on a larger scale.

Negotiations with Cleveland capitalists lasted some six months, the principal stumbling block being the division of interests in the future commercial development of the process. Hall was willing to give a good share of his patent rights for funds to continue developing his process, but insisted on having at least one-fourth interest in the company organized to work the process. Meanwhile, the United States patent office declared an interference between Hall's application and that of Héroult, and this forced matters to a head, so that in the summer of 1887 Hall entered into an agreement with the Cowles Electric Smelting and Aluminum Co., under which Hall was to have electric current and facilities for experimenting at the Cowles works, at Lockport, N. Y., giving in return a six months' option on his process, in exchange for a certain fraction of the stock of that company. After six months the option was renewed for three months more, but at the end of nine months the option ceased, without the company carrying it into effect. Mr. Cowles' statement of their reason for letting the process pass from their control is that the results, as far as they saw, were not sufficiently encouraging. Mr. Hall's statement is that he figured up that he then made aluminum at the rate of one pound per horse-power per twenty-four hours, but that the current at his command was so small that he would work many hours over a hot fire to make a few ounces of aluminum, and that all that was needed was to apply the process on a larger scale. We will go no further into this controversy, which probably never will be settled satisfactorily to all concerned, and so we merely state the two sides.

Romaine Cole, also employed at the Cowles works, undertook at this juncture to interest capital in the process. He interested Capt. A. E. Hunt and Mr. Mellon, the banker, of Pittsburg, and in August, 1888, the Pittsburg Reduction Co. were organized, with a capital of $20,000, and work on an installation being at once commenced, the company were turning out aluminum commercially by November, 1888.

Meanwhile, the interference in the patent office had been decided in favor of Mr. Hall, and the business was clear of incumbrance and entered on an era of continuous development.

In 1891 the plant was moved to New Kensington, 16 miles from Pittsburg, on the Allegheny River; in 1893 a contract was made with the Niagara Power Co. and the "upper works" started, using 1,800 horse-power, in 1895, and since increased to 3,600 horse-power. In 1896 the "lower" Niagara plant was started, using 3,500 horse-power, since increased to 6,500 horse-power. Since then the company have bought bauxite mines in Georgia and Arkansas, have started a 5,000 horse-power reduction plant at Shawinigan Falls, Quebec, and are commencing on a 10-acre plant at Massena, N. Y., which will utilize 12,000 horse-power.

In connection with these developments, Mr. Hall has invented several important improvements.

# NIAGARA AS AN ELECTROCHEMICAL CENTRE.

## THE ELECTROCHEMICAL INDUSTRIES OF NIAGARA FALLS.

By JOSEPH W. RICHARDS, PH.D.
*President of the American Electrochemical Society.*

THE second meeting of the American Electrochemical Society, inaugurated in Philadelphia, April 3d, of this year, is with the greatest propriety scheduled to be held at Niagara Falls, in September, of this year. Although Philadelphia may with right claim to be the birthplace of the American Electrochemical *Society*, Niagara Falls may with equal right claim to be the home, *par excellence*, of the American electrochemical *industry*. Here, within a radius of two miles from the greatest source of water-power in the world, have grown up within the short space of eight years more than a dozen varied electrochemical industries; here, using power which costs less than half as much as power can be generated from coal (even if the coal were to be had for nothing), have grown up and developed into commercial successes processes which but a decade ago were merely ideas, visions in the fancy of a few electrochemical enthusiasts. The old adage, "knowledge is power," is being improved upon: the keynote of success at Niagara is "knowledge *and* power."

No field in the whole range of the applied sciences is succeeding more signally, promising more attractively, or so pregnant with suggestions of future applications, than electrochemistry. In the hands of the masterful chemist, acquainted with the facts of chemistry and the needs of civilization, the uniting and decomposing powers of the electric current, its almost infinite control of chemical analysis and synthesis, the generation of inconceivable temperatures on a commercial scale and the methods it furnishes of torturing poor Mother Nature into new shapes and wringing from her new secrets, has brought to realization fancies which were undreamed of by the alchemists.

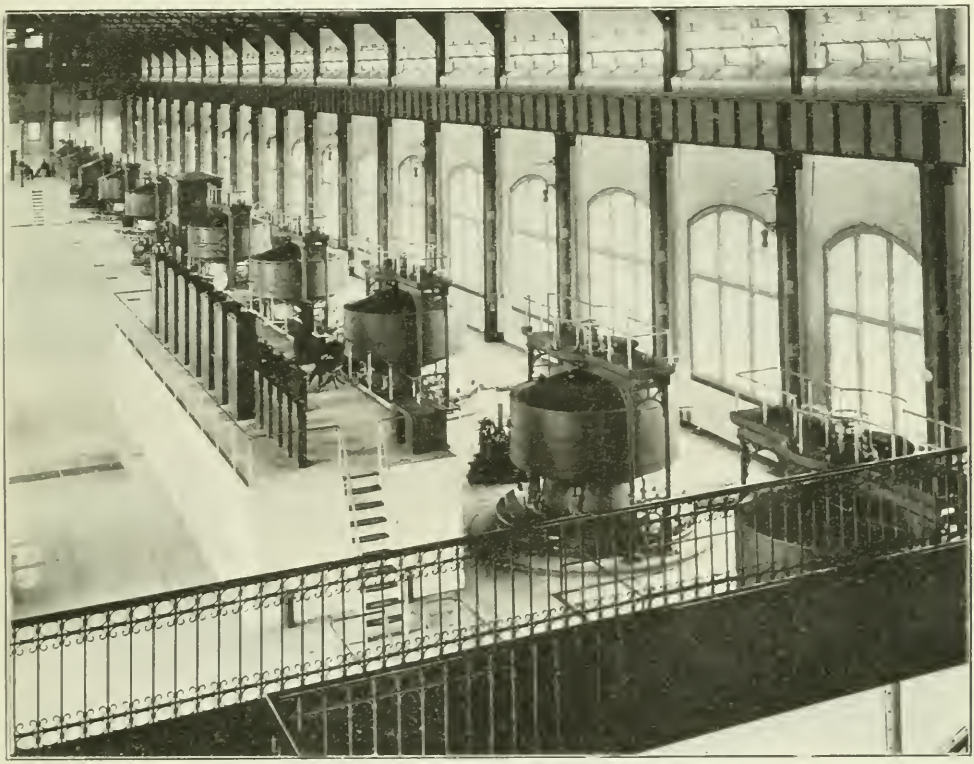


FIG. 1.—POWER HOUSE NO. 1, NIAGARA FALLS POWER CO.

Combined with all the necessary supply of power, Niagara unites almost every other requirement for commercial development. The great lakes, with 3,000 miles of shore line, and navigable to the very docks at Niagara, give the cheapest sort of transportation to markets representing nearly half the population of North America, besides furnishing in many cases the cheapest sources of raw materials. Railways radiate therefrom in all directions; and, to add to it all, the falls with their great facilities are equally within two different countries, under different governments, one on a protection basis as regards imports, the other practically free trade, and the manufacturer can take his choice as to which policy is most favorable to his industry. He can even place one works in America,

NOTE.—Owing to limitation of space, descriptions of the following plants are reserved for the following issue: Pittsburg Reduction Company, International Acheson Graphite Company, Carborundum Company and Acker Process Company.—ED.

to enable American trade to come to Canada, to supply foreign trade. Truly, Niagara does present an almost embarrassing combination of advantages.

The canal to the edge of the gorge was built in 1861, and supplied power to several works and mills, who utilized from 20 to 50 feet of the possible 160-foot fall thus supplied. The canal was purchased by the Niagara Falls Hydraulic Power and Mfg. Co. in 1887, who increased the facilities for providing power and supplied it to some additional shops; but the great consumers of power—the electrochemical industries—were not yet far enough developed to enter the field, and the development of this great water power had to wait upon the opening of the electrochemical industry for its great *raison d'être, the developing electrochemical industry gave incentive for and is practically the mainspring of the development of power at Niagara Falls.* By the end of this year the Niagara Falls Power Co. will be developing 60,000 horse-power, 45,000 of which, or exactly three quarters, will be used in electrochemical work.

The Hydraulic Power and Mfg. Co. have a canal, 36 feet wide and 8 feet deep, reaching from above the falls to the sides of the gorge below the town, on the American side, giving a head of 210 feet to the river below. Their principal power plant is located in the gorge at the water's edge and develops 30,000 horse-power, while 5,000 horse-power additional is generated by several smaller plants using only part of the available head, as is shown in the photograph by the various cataracts descending the cliff. This company have now the right to enlarge their canal to 100 feet in width by 14 feet in depth, which will give, it is estimated, a total of over 100,000 available horse-power. The selling price of this power varies from $8 per horse-power per year, for those buying only the water right and putting in their own machinery, to $20 or $25 per horse-power per year for those buying the working current, adapted to their particular use.

The Niagara Falls Power Co., on the American side, above the falls, have wheel pits, 180 feet deep, connected with a tail-race tunnel, 21 feet in diameter by 1⅓ miles long, whose capacity to take away water is rated at 120,000 horse-power. The

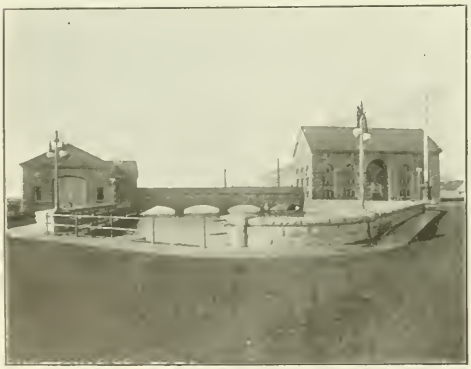


FIG. 2.—POWER HOUSE NO. 1 AND TRANSFORMER STATION, NIAGARA FALLS POWER CO.

per horse-power per year, transforming it at their own cost in present working station has ten 5,000 horse-power units in operation, and 5,000 horse power additional to operate the local street railway system. The International Paper Co., located alongside this power house, have their own wheel pit and generating machinery, and use the tunnel for their tail race, thus employing 10,000 horse-power, for which is paid $9 per year. Other companies using power from this plant receive the current at 2,250 volts, alternating, and pay for it $18 to $20 whatever way may be necessary for their special purposes. This company own 1,500 acres of ground, which is reserved for manufacturing purposes, and held at about $1,000 per acre. The company are at present constructing a 55,000 horse-power plant, which is already under roof (as shown in photograph) and which will furnish the first 10,000 of their power in October, and it is an interesting feature that several of the works are now erecting additions, and that this first 10,000 horse-power was all contracted for several months in advance.

FIG. 3.—STATION NO. 2, NIAGARA FALLS POWER CO.

The Canadian-Niagara Falls Power Co. pay the Canadian Park Commission $25,000 per year for the right to develop 250,000 horse-power on the Canadian side. Their power house, immediately to the left of the falls, is well under way, and will begin furnishing power in July, 1903. Other concessions have been made allowing 200,000 horse-power more to be developed on the Canadian side, but they are not yet being exploited.

### THE CASTNER ELECTROLYTIC ALKALI CO.

This company were originally the Mathiessen Alkali Co., a branch of the Providence works of that company, and operated the Castner process first at Saltville, Va., in 1895. The present company may be considered the American representative of the Castner-Kellner Co. of England. The officers are B. F. Thurston, president; Max Mauran, superintendent. The patents operated under are those of H. Y. Castner (U. S. Patent 528,322, of 1894), and Max Mauran (U. S. Patents 674,927 and 674,930 to 674,934). The patent of Mr. Castner (who is now deceased) is the basic one, covering the principle of using a compound cell with movable mercury floor, partitions dipping into the mercury separating the cell into compartments, which are electrically independent of each other, and moving the mercury from one compartment to another by any mechanical means. The patents of Mauran are directed towards greater mechanical perfection of the details of the cells, but in no wise alter their principle of action.

The Castner cell, as installed by Mr. Castner, at Niagara, is a slate box, 4 feet wide, 4 feet long and 6 inches deep, the joints being made by rubber cement. Two partitions reaching within 1-16 of an inch of the bottom (under which are made grooves) divide the cell into three compartments, each 15 inches wide by 4 feet long, which are made independent of each other by mercury on the bottom and in the grooves, touching the partitions. The general plan of the process and its theory are so well known that it is unnecessary to rehearse them here, and we will confine our description to the actual apparatus used. The exterior compartments, through which brine flows, have numerous graphitized carbon anodes passing

FIG. 4. STATION OF THE NIAGARA FALLS HYDRAULIC POWER AND MFG. CO.

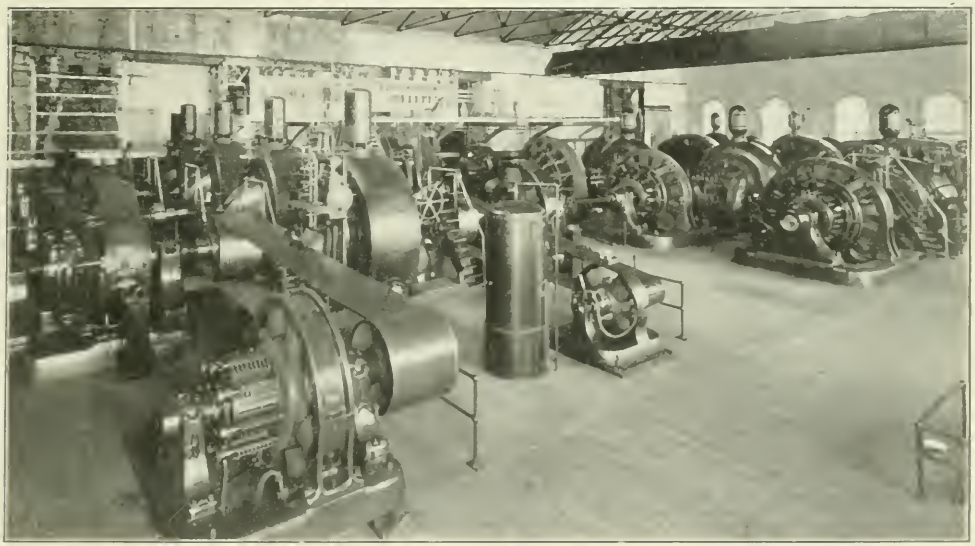


FIG. 5. NIAGARA FALLS HYDRAULIC POWER AND MFG. CO'S STATION IN GORGE.

through the sides of the box with 1 inch of the surface of the mercury. There are 12 electrodes on each side, each 1 inch in diameter by 15 inches long. These compartments are provided with tight covers and exit pipes of rubber, connecting with lead pipes to carry off the chlorine. The central compartment has 20 sheets of iron hanging in it, which serve as cathodes for liberating hydrogen in the caustic soda solution. This compartment is supplied with pure water; it is covered loosely with a sheet lead cover, and the liberated hydrogen escapes into the room. The cell is pivoted on two points on one side and rests on an eccentric on the other, which raises and lowers about ¼ inch, once a minute. This suffices for the circulation of the mercury between the outer, or charging, and the inner, or discharging, compartments. The current passes through the brine in the outer compartments, liberating chlorine at the graphite anodes and charging the mercury with sodium; it then passes from the mercury in the central compartment to the iron cathodes, liberating hydrogen therein and setting free caustic soda in the solution. Only 90 per cent. of the charging current is allowed to pass through the discharging cell, because the efficiency of charging is not quite 100 per cent., while that of discharge is 100 per cent. or over, and the margin of 10 per cent. must be allowed in order not to oxidize the mercury by having a deficiency of sodium to discharge. This appears to be one of the severest difficulties of the process. The salt solution flows through continuously; the salt is from

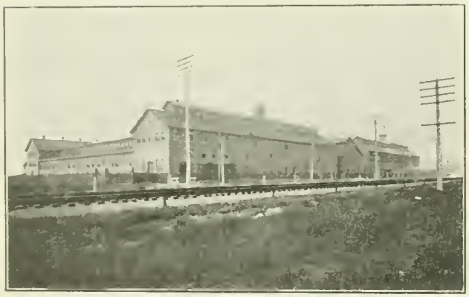


FIG. 6.—CASTNER ELECTROLYTIC ALKALI CO.

the New York beds at Retsof, containing very little magnesium and but a small proportion of sulphates. The strong salt solution is not purified before going to the cells. On returning, it is strongly charged with chlorine, and has to be pumped by earthenware pumps. The sulphates accumulate to a certain point, when part of the solution is withdrawn from circulation, purified by use of barium chloride and returned to the circulating system. Water is run into the center compartments and allowed to remain until it has reached a certain concentration (54° Twaddell), and then run off and replaced by fresh water. The caustic solution is evaporated to solid caustic in iron pans, 10 feet in diameter by 6 feet deep, and it will be readily seen that the stronger the solution from the cells the less evaporation is needed. The cells last indefinitely, the graphite anodes last one to two years, the iron cathodes are unchanged. The mercury is unattacked as long as sufficient of the charging current (averaging 10 per cent.) is shunted off from passing through the discharging cell. If the operator is anxious to "sail close to the wind" he may shunt off too little, and immediately blacken the mercury and cause the formation of mercury salts. Each cell contains in the neighborhood of 100 pounds of mercury, which costs more than the rest of the apparatus. (Slate apparatus is made in the Pennsylvania slate regions at prices hardly greater than if made of wood.)

The improvements on the original Castner cell by Mr. Maurau have been as follows: a more efficient cathode has been made, the iron sheets being replaced by an iron grid (like an inlet grating), consisting of 20 strips the length of the cell, 1 inch deep and about ½ inch apart, united at the ends, where they rest on the cell walls, in order to make connections. The graphite rods passing through the sides of the box gave frequent trouble from leakage and offered considerable resistance. They have been replaced by blocks having much the shape of a rail section, which are cemented into the lid of the compartment, with their broad lower flanges offering large surface within ½ inch of the mercury, their upper parts projecting above the lid are connected by zigzag lead connections and paraffined heavily to preserve the contacts. The voltage necessary to run the cells has thus been decreased some 20 per cent.

Each cell receives 630 ampères and absorbs 4.3 volts. The voltage absolutely necessary for the decompositions is 2.3 volts, so that 53 per cent. of the energy of the current is actually used in the chemical transformation and 47 per cent. converted into heat. The watts thus converted into heat are, however, only 1,260, which would suffice to keep the cell only a few degrees above the normal temperature. The temperature of the cell may, in very hot weather, approach the danger line of 40° C., at which chlorate begins to be produced, but artificial cooling has not yet been found necessary with the current densities used. The current density at the mercury is 110 ampères per square foot, at the graphite anodes probably 150. The efficiency attained, calculating on the ampères of the charging current, is very close to 90 per cent.

The first plant at Niagara Falls, situated three-quarters of a mile above the upper power house, occupies a tract of ground 150 yards square. It contains storage rooms, power-converting plant, cell room, 200 feet square, evaporating house with ten evaporating pots and large bleaching-powder chambers. The power room contains ten stationary converters, each connected with a rotary converter. The 2,250-volt alternating current, supplying 700 ampères, is thus split up into currents of 70 ampères each, which are converted by the ten rotaries into ten currents of nearly 200 horse-power each, *i. e.*, 230 volts by 630 ampères. Each such current runs a double row of 54 cells in series. The theoretical quantity of materials treated per day of twenty-four hours, reckoning on an efficiency of 90 per cent., is as follows (in pounds):

| | Per Cell | Per 540 Cells | Per H.-P. |
|---|---|---|---|
| Crude salt decomposed..... | 65.25 | 35,200 | 17.6 |
| Caustic soda produced..... | 44.62 | 24,100 | 12.0 |
| Bleaching powder produced (36 per cent. chlorine).... | 111.54 | 60,200 | 30.1 |

The plant at Niagara was enlarged in 1901 by the construction on a neighboring site of a 4,000 horse-power plant, working on the same principles. The whole plant at Niagara represents, therefore, a capacity of 6,000 horse-power, using over 50 tons of salt daily, and producing therefrom 36 tons of caustic soda and 90 tons of bleaching powder. The 3,000 horse-power Acker process plant has about the same capacity as the 2,000 horse-power Castner plant. Between the Acker and Castner processes it is estimated that they produce nearly one-half of the caustic soda made in America.

Analyses of the caustic soda produced by the Castner process show it to contain 97 to 99 per cent. caustic, 1 to 2 per cent. of sodium carbonate (from contact with the air), 0.3 to 0.8 per cent. of sodium chloride, 0.03 to 0.10 per cent. of sodium sulphate and 0.05 to 0.10 per cent. of sodium silicate. The sulphate comes mostly from the water used to take up the caustic, the chloride from leakage from the brine chambers and the silicate from corrosion of the slate cells.

### THE NIAGARA ELECTROCHEMICAL CO.

This company were formed to work the processes of H. Y. Castner for producing sodium, sodium peroxide and sodium cyanide. The manufacture of the first two is conducted at

Niagara, of the latter at Roessler and Hasslacher's works at Perth Amboy, N. J. The company were incorporated in 1895, and the principal stockholders are the Aluminum Co., Ltd., Oldbury, England, the Deutsche Gold and Silber Scheide Anstalt vormals Rossler, of Frankfort, Germany, and Rossler and Hasslacher, 100 William street, New York. The English and German firms named also conduct similar manufactures under Castner's patents. The officers of the company are Franz Rossler, president; J. Hasslacher, secretary and general

FIG. 7.—NIAGARA ELECTROCHEMICAL CO.

manager, and Geo. F. Brindley, chemist and manager of the Niagara plant. The capital is $100,000.

Castner's patent for producing metallic sodium is the U. S. Patent 452,030, of May 12, 1891; for producing sodium peroxide, U. S. Patent 494,757, of April 4, 1893; for producing cyanides, U. S. Patents 541,006, of June 18, 1895, 543,043, of July 30, 1895, and 577,837, of March 2, 1897. Only the first named is an electrochemical process.

The process consists, according to its claims, in electrolyzing caustic alkali constantly maintained at not more than 20 degrees above its melting point; and, also, in using a gauze or screen between the electrodes and a superposed dome for collecting the metal. The temperature must be kept low in order to prevent the resolution of metal by the bath and re combination, which take place actively at higher temperatures. Caustic soda melts at 308° C., if pure, but down to 300° if it contains slight impurities. It is electrolyzed preferably within 10° of its melting point, but never above 325°. Within five degrees of its melting point, almost the theoretical quantity of sodium is obtained, at ten degrees above, about 90 per cent., and this is the best attainable in commercial practice, above this the yield decreases very rapidly, and at 50 degrees above its melting point re combination is so active as decomposition and the bath yields no metal. At this "dead

On commencing to pass the current through melted caustic soda, any water present is at first decomposed, evolving hydrogen and oxygen only until every trace of water has gone. After that sodium and hydrogen together appear at the cathode, and oxygen at the anode. These must be kept rigorously separated or re-oxidation of the sodium will ensue, and the hydrogen will be oxidized, with an explosion. Castner achieves this by hanging a gauze or screen all around the cathode, the meshes of which are large enough to allow the electrolyte to circulate through it freely, but small enough to prevent either globules of sodium or bubbles of hydrogen or oxygen gas from passing through. The sodium collects on top of the electrolyte, and is thence run off or ladled out.

Castner's apparatus consists of a conical iron pot, 18 inches in diameter by 2 feet deep, set in brick work. The carbon cathode comes up through the bottom, through a fireclay tubular prolongation, 12 inches long, in which to build caustic sets and forms a tight joint. The top of the rod has a enlargement 4 inches in diameter, standing about 3 inches and

side of the pot; this is the active cathode. Surrounding this is a 6-inch circular anode of iron or, better, nickel, and between these is a 5-inch circular cylinder of nickel mesh, suspended from a solid 5-inch cylinder, which reaches above the surface of the caustic and is covered over by an iron lid having small holes for escaping hydrogen. Such a pot holds 250 pounds of melted caustic, and a current of 1,200 amperes is passed through it, dropping 5 volts in a pot. The current density at the cathodes is, therefore, about 2,500 amperes per square foot and at the anodes 1,500. Four rows of 10 such pots are in operation at this plant, using 1,000 horse-power and producing daily, at an assumed efficiency of 90 per cent., 52 pounds of sodium per pot, or 0,250 pounds for the whole plant. This is a little less than 4 horse-power per hour per pound of sodium, whose cost would be only 2 cents. Since caustic soda costs only 2 cents per pound or 4 cents per pound of sodium produced, and the labor should not amount to over 3 cents per pound, while deterioration of apparatus remelting and packing may be put at 2½ cents more, the minimum cost of sodium by this process is probably not over 10 cents per pound. Its market price is 35 cents per pound, but the demand for the metal is limited. The greater part of the product is converted into sodium peroxide, by passing air over the sodium at a certain temperature in iron tubes. The product contains 95 to 97 per cent. of peroxide and 3 to 5 per cent. of carbonate and moisture, and commands 35 cents per pound in ton lots.

The *bete noire* of the sodium business has always been the limited demand and restricted uses for the metal. That this company is successfully solving the problem is evidenced by the doubling of the size of the works last year. The present plant covers two acres and employs 60 men. May they see increase!

### THE NORTON EMERY WHEEL CO.

This is an old-established firm, located at Worcester, Mass., which have purchased from the Ampere Electrochemical Co. the patent of Chas. B. Jacobs for fusing bauxite in an electric furnace and thereby producing a pure artificial corundum. This process consists in fusing the natural bauxite and allowing it to cool slowly, when it acquires the hardness of

FIG. 8.—[illegible]

corundum and the machines are nearly [illegible] wheels, emery paper and cloth, [illegible] abrasives.

The process was originally patented at the time of the Ampere Electrochemical Co., by a reduction furnace of the Harvey Jarbuh type. During the process [illegible] electrodes carbon [illegible] [illegible] [illegible] and bauxite is [illegible] [illegible] and [illegible] [illegible] [illegible]

The works of the Norton Emery Wheel Co. are situated about one mile above the upper power house, and is a brick building, two stories in height, covering 60 by 90 feet, erected in 1901. The gentlemen in charge are A. C. Higgins, general manager, and S. F. Hall, superintendent. The building contains office, laboratory, calcining furnace and melting furnaces. The bauxite is first taken to the upper floor, where it is charged into the upper end of a calcining furnace fired by coal. Here the bauxite is completely calcined, and is taken out at the lower floor level. It is then hoisted to the upper floor, where the melting furnaces are operated. The power used is 500 horse-power. The method of operation is similar to that of the experimental work already described, and is carried on in furnaces into which dip the two carbon terminals. These terminals dip into the melted bath, and fresh bauxite is added as soon as the contents are melted. The method of regulating the distance of the carbons in the bath and of protecting the furnace lining are matters which have been very satisfactorily solved.

After a run the carbons are taken out and the mass allowed to cool three or four hours in the furnace, after which the block is removed from the furnace and left on the floor to cool. Then it is broken up into pieces of convenient size, roughly sorted and shipped to the main works at Worcester, Mass. The best product is horny, or flinty in appearance, while some beautiful small crystals of pure alumina are at times found, colored blue, like sapphire, or pink, like ruby. They are, in fact, the artificial gems, but too small to possess value as such.

### THE UNITED BARIUM CO.

This company were formed to acquire and work the processes of working barium sulphate into other barium salts, which was developed to commercial working by the Ampère

Fig. 9.—United Barium Co.

Electrochemical Co. The officers of the company are G. S. Ettla, president; W. H. Miller, vice-president; J. G. Petrekin, treasurer, and T. L. Welles, works superintendent.

The process acquired is that patented by C. S. Bradley and C. B. Jacobs (U. S. Patent 624,041, of 1899; German Patent 111,667, of December 16, 1898). The principle employed is that of melting in an electric furnace a mixture of barium sulphate with a small quantity of carbon, usually only one-nineteenth of its weight. If sufficient carbon is present, all the sulphate is reduced in the electric furnace to sulphide, according to the reaction

$$BaSO_4 + 4C = BaS + 4CO$$

requiring one part of carbon to five parts of sulphate, and reproducing the ordinary furnace reaction for making the sulphide. If barium sulphate and barium sulphide are fused together, at the heat of an electric furnace, however, they will react according to the formula

$$3BaSO_4 + BaS = 4BaO + 4SO_2,$$

but this reaction cannot be produced at ordinary furnace heats. If, therefore, just one-fourth as much carbon is used as is necessary to reduce the sulphate to sulphide, the one-fourth of sulphate reduced to sulphide reacts upon the unchanged three-fourths and the oxide is obtained. The sum total of the two reactions, written altogether, is

$$BaSO_4 + C = BaO + SO_2 + CO.$$

The reaction is not perfect, however, and in general only about two-thirds of the sulphate is converted into oxide, nearly one-third remains as sulphide and only a very small fraction remains unchanged, some 1 to 3 per cent.

There are two furnaces now in operation working this process. They are of the direct-heating arc type, the carbons being adjustable and playing an arc onto the fused material. The body of the furnace is lined with carbon blocks, and the contents are tapped out from time to time as the furnace gets full of melted material. The carbons are raised and lowered by means of small electric motors, controlled by the workmen, and pass through a square opening in a grid of wrought-iron pipes, cooled by a stream of water, and covered with a non-conducting cover. The workmen can thus feed in material while standing close to the furnace, but the mixture of barium sulphate and carbon must be fed in slowly, because the gases evolved by the reaction are large in volume and would cause violent boiling if melted too quickly. Attempts are being made to recover the sulphur dioxide evolved, so as to convert it into sulphuric acid. Each ton of sulphate furnaced gives off enough of this gas to make one-half a ton of 50 per cent. sulphuric acid.

The plant is being enlarged so as to manufacture 60 tons of barium hydrate, $Ba(OH)_2 \cdot 8H_2O$, per day. The present output is stated to be 12 tons daily. There are three 400 horse-power furnaces, each taking 2,500 ampères at 120 volts, and at this output, allowing that only 60 per cent. of the sulphate is reduced to oxide, the efficiency of the furnaces would count up 74 per cent. absorbed in heating up and melting the mixture and in the chemical reactions, while 26 per cent. would be lost by radiation.

The furnace product is tapped out, running into cakes about 3 feet by 4 feet and 3 inches thick. This is broken up and digested with hot water, leaving very little insoluble sulphate, but the material is about 60 per cent. barium oxide and 40 per cent. barium sulphide, which go into solution as 60 parts hydrated oxide, 20 parts sulphide and 20 parts sulphydrate. On cooling the filtrate, the hydrate, $Ba(OH)_2 \cdot 8H_2O$ crystallizes out and is separated in centrifugals. When dried and packed it sells at 3 cents per pound. The mother liquors are treated to recover their barium as carbonate and also to recover the sulphur in them, by methods which are not yet quite worked out and which the company are not ready to publish.

The raw material, barite from Missouri, costs $2.50 per ton where found, but the railway freight raises its cost to some $6 per ton at Niagara. It is about 90 per cent. pure. To obtain cheaper material, the company have acquired a remarkable deposit of barite on the north shore of Lake Superior near Silver Island. The cliff here is 50 feet high, and a vein of pure white barite, 77 feet wide, with perpendicular strike, is exposed for the whole height of the cliff and is visible 30 feet down in the water, while it has been traced on shore a distance of 600 feet back from the water. At a moderate calculation, 250,000 tons of barite are in sight, which can be shipped from the spot to the company's wharf at Niagara more cheaply than Lake Superior iron ore can be carried to Pittsburg.

The uses of the company's products are various. Barium hydrate finds application in the paint trade, for making white paints; in the sugar trade, for recovering sugar (as insoluble

barium saccharate) from waste dilute solutions, and for softening boiler waters. The mother liquors from the crystallization of hydrate, containing barium sulphide and sulphydrate, have been found useful in removing hair from hides, a solution diluted to 2½ per cent. removing all the hair from a hide in 3½ hours' immersion, without any injury to the leather. The same solution is very suitable for making the white paint called *"lithophone,"* which is made by running a solution of zinc sulphate into barium sulphide solution, thus producing the precipitated pigment, a mixture of barium sulphate and zinc sulphide. The mother liquors can also be converted into barium carbonate, which has found application in the cyanide industry and also in the manufacture of bricks; for mixed in small proportion with the clay it is said to prevent red bricks from turning white and white bricks from turning green.

Such are some of the many ramifications of the electrical-barium process, and in the further prosecution of that most interesting business we wish our Niagara friends *bon voyage.*

THE OLDBURY CHEMICAL CO.

This company are virtually the American branch of Albright and Wilson, manufacturing chemists of Oldbury, England. Their New York agents are J. L. and D. S. Riker, Cedar street, New York. Hugh A. Irvine is the manager. The plant is near that of the Roberts Chemical Co., and uses 1,000 horse-power in the production of yellow phosphorus and potassium chlorate. The works cover 3½ acres and employ 60 men. The output of chlorate is given as 30,000 pounds per month and that of phosphorus an equal amount. If these figures are reliable, the current efficiency of the works is exceedingly high, compared with others in the same lines.

The Readman-Parker process of producing phosphorus is used, in which natural phosphate is intimately mixed with carbon and sand, and placed in a retort-like furnace heated inside by the electric current passing between carbon poles, it being a type of resistance furnace. The phosphorus distills off and is condensed under water, the calcium silicate slag is tapped out intermittently. About 80 to 90 per cent. of the phosphorus in the raw material is recovered and only 170 pounds a day are obtained from one furnace. *(Mineral Industry,* Vol. VII.) It would take, therefore, six furnaces to make the output quoted, which would be of 50 horse-power each.

Mr. Irvine has patented an improvement on the method of heating the charge in his furnaces (U. S. Patent 681,367) consisting essentially in using a granular core of carbon as a heating agent, surrounding it with the charge material and passing the current. As soon as the charge melts, forming a body of slag, the carbon floats up and the current thenceforth passes through the slag, which then serves as the vehicle for melting fresh portions of charge.

THE AMPÈRE ELECTROCHEMICAL CO.

This company are a decided innovation, in that they are not an operating company, but an experimenting company, formed to discover and develop new electrochemical processes and bring them to the point of commercial application. The founders of this company were Prof. F. B. Crocker, president; C. A. Doremus, vice president; S. S. Wheeler, treasurer; C. S. Bradley, inventor, and they have associated with them A. H. Buch, H. E. Knight, D. R. Lovejoy, Chas. B. Jacobs and N. Thurlow as chemists. The company originally located at Ampère, N. J., but in 1898 established themselves at Niagara. The processes so far developed by this company are as follows: the method of fusing bauxite to produce artificial corundum, sold to and now operated by the Norton Emery Wheel Co.; the method of treating barite (natural barium sulphate) to produce barium hydrate, sold to and now operated by the United Barium Co.;

FIG. 9.—OLDBURY CHEMICAL CO.

the method of producing nitric acid from nitrogen and oxygen, operated by the Atmospheric Products Co.; a method of producing camphor from turpentine, discovered by Mr. Thurlow, and being now installed at Port Chester, N. Y., on a scale sufficient to produce one ton of camphor per day. Besides these, the company are working on the production of cyanides by the fixation of atmospheric nitrogen, the production of artificial rubber, the production of new fertilizers and the manufacture of several new silicides. We will consider by themselves the processes already being operated at Niagara by other companies, and will under this heading describe only those processes of the Ampère Electrochemical Co. which are in process of development.

*Manufacture of Cyanides.* By heating a mixture of barium oxide or carbonate with carbon in the electric furnace, barium carbide quite similar to calcium carbide is obtained. Its formula is $BaC_2$, and it is very probable that it is an unsaturated compound of the same type as acetylene, $H_2C_2$, and, therefore, containing two carbon atoms, which temporarily neutralize each other's affinities. Such compounds easily form additional compounds, and it has been found that by heating the barium carbide and passing nitrogen gas over it, the latter joins onto the carbon and forms barium cyanide, $BaC_2N_2$. Air will not

[illegible] oxygen would oxi[illegible] but the oxygen must either [illegible] which may be done [illegible] a process amounting to [illegible] With this gas as the reagent, the cyanide [illegible] but little oxidation. The mass being [illegible] the cyanide goes into solution, and may [illegible] soda salt, such as the carbonate, to [illegible] and leave in solution the sodium [illegible] Another alternative is to treat the barium cyanide [illegible] with dilute acetic acid, under reduced [illegible] and passing the hydrocyanic acid gas into caustic soda [illegible] produce the cyanide, leaving barium acetate behind. The [illegible] evaporation and distillation of the latter in a closed [illegible] leaves behind barium carbonate and distills off very pure [illegible] much purer than is commercially obtained from cal[illegible] acetate. The barium carbonate is then used over.

The company are now working industriously on the commercial installment of the process above outlined, which, experimentally, has promised very good results.

*Manufacture of Ammonia.*—There is a possibility that by passing steam over the barium cyanide, ammonia may be made in commercial quantities by the reaction

$$BaC_2N_2 + 3H_2O = BaO + 2NH_3 + 2CO.$$

The writer does not know how far this possibility has proven successful

*Manufacture of Silicides.*—In July, 1899, this company succeeded in producing the silicides $CaSi_2$, $BaSi_2$ and $SrSi_2$, which are analogous to the carbides $CaC_2$, etc. (U. S. Patents to Jacobs, 656,353 and 656,354, of 1900). They are formed in the electric furnace by heating to a comparatively high temperature (higher than that needed for carbides) a mixture of carbonate, oxide, sulphate or phosphate of the metal concerned with silica and sufficient carbon to effect the reduction; as, for instance, according to the reactions

$$BaO + 2SiO_2 + 5C = BaSi_2 + 5CO.$$
$$BaSi_2O_5 + 5C = BaSi_2 + 5CO.$$

These silicides are crystalline, bluish-white, and in contact with water give pure hydrogen, by the reaction

$$BaSi_2 + 6H_2O = Ba(OH)_2 + 2SiO_2 + 5H_2.$$

One pound of calcium silicide will thus generate, in a common acetylene generator, 18.5 cubic feet of pure hydrogen; or it would require 54 pounds per 1,000 cubic feet of hydrogen. These qualities suggest a field for generating hydrogen in the laboratory or for ballooning purposes. It is also stated that barium silicide has the property, if put into melted iron or steel, of combining with the sulphur and phosphorus present therein, removing them in the slag as barium sulphide or phosphide, and experiments made on steel at Newark are said to have succeeded in removing the injurious sulphur and phosphorus completely. They are also good reducing agents, working in either acid or neutral solutions.

*Manufacture of Camphor and Rubber.*—These are made from turpentine by a purely chemical process, not electric, so their consideration is here omitted.

These are but a part of the ideas which this company are working up into commercial processes, and if one considers the combination of forces which this company command—some veteran inventors, some college professors, some college-trained chemists and electricians, some business men, and all enthusiastic, persevering workers—it is safe to predict that many more valuable processes will be brought to light as their record

THE ELECTRICAL LEAD REDUCTION CO.

This company were organized to work the electrolytic method of reducing lead sulphide or native galena, patented by Pedro G. Salom, of Philadelphia. The officers are Pedro G. Salom, president; Henry G. Morris, vice president; F. H. Deacon, secretary and treasurer. The chemist is A. L. Weightman; superintendent, S. Weil. The company have a paid-in capital of $200,000, they issue preferred stock $2,000,000 and common stock $10,000,000.

The process has been described by Mr. Salom in the *Transactions of the American Electrochemical Society*, Vol. I, 1902. The idea of the process is, briefly, to use crushed and pure galena as cathode in a dilute solution of sulphuric acid, where it is reduced, the sulphur going off as hydrogen sulphide. Two Westinghouse 300 horse-power motors are run on the

FIG. 11.—ELECTRICAL LEAD REDUCTION CO.

alternating current of 2,250 volts, and each is directly connected with a Westinghouse direct-current 250 horse-power generator. The reduction pans are of antimonial lead, 15 inches across at the bottom and 18 inches at the top, round and 6 inches deep. The galena is spread on the bottom in a layer of fine material, 1 inch thick, dilute sulphuric acid is put in, the sides of the pan are protected by a rubber lining, and the bottom of a similar pan placed on top becomes the anode. The pans are thus stacked 11 high, the bottom of each pan serving as anode to the pan beneath it. Thirty-three pounds

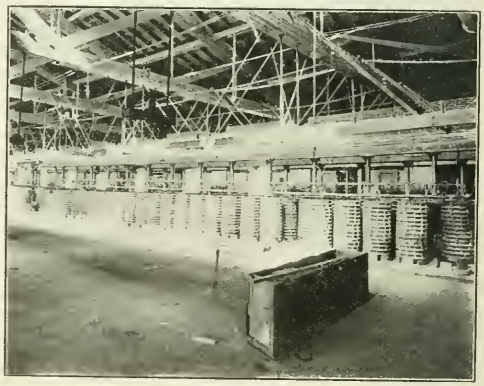


FIG. 12.—CELL ROOM, ELECTRICAL LEAD REDUCTION CO.

of galena is thus subjected to a current of .33 ampères, requiring 2.9 volts, and is treated 5 days. The ore is reduced *in situ* to spongy metallic lead, swelling up to 3 or 4 inches thickness. The gases escaping are a mixture of hydrogen and hydrogen sulphide, the proportion of the latter in the gas gradually increasing from zero to a maximum, in one day, and then gradually declining. The stacks are grouped in fours, run in parallel, so that the current of 125 volts runs through four stacks in series (equals 44 pans) and runs through several of such groups in parallel.

The cell room is 140 by 182 feet, and has room for 10 rows of 22 stacks each, whose capacity would be 10 tons of lead per day. Only two of these rows have been installed so far, but the rest of the room is being filled with an improved type of cell, which works much more quickly and satisfactory, and which will be described by Mr Salom before the Niagara meeting of the American Electrochemical Society, on September 15th, next. This apparatus is particularly designed to obviate the incompleteness of reduction, which has given considerable trouble

The gases escaping are conducted in lead pipes to a combustion chamber, where they are burned, either completely, so as to recover sulphuric acid, or incompletely, so as to recover sulphur. The spongy lead is first washed on a sloping table, with a hose, and using a hoe in order to remove light impurities, such as quartz, zinc sulphide, etc. It is then dried in a revolving cylinder of iron over a furnace. It is then ready for use in storage batteries. Most of it is converted into litharge, by burning it carefully on the hearth of a reverberating furnace. In this way an hour's treatment converts it completely into litharge, which is cooled, washed, to remove any unconverted lead, and dried. The product is clean and pure, and finds a ready market with glass and rubber makers. Mr. Salom has also patented processes for the conversion of this sponge into other lead salts, such as carbonate, chromate, dioxide and for pressing it into a compact storage-battery plate.

The process is based on sound electrochemical principles and also sound economic principles. The electrochemical equivalent of lead is so high that very little electric power is needed to reduce it; theoretically, for instance, a current which would liberate 1 part of aluminum would set free 11½ parts of lead. The process furnishes the lead in a condition highly suitable for solution or corrosion or conversion into other lead salts, while it is in exactly the condition required for storage-battery work. If Mr. Salom can secure the complete reduction of all galena, his process will have an economic future which his present Niagara plant will not be able to take care of.

### THE ROBERTS CHEMICAL CO.

The plant of this company is nearly two miles from the upper power house. It is a one-story frame building, 60 by 200 feet, and utilizes 500 horse power in the manufacture of caustic potash and hydrochloric acid from potassium chloride. The officials of the company are W. S. Block, president; H. G

FIG. 13.—THE ROBERTS CHEMICAL CO.

Wilson, treasurer; S. D. Benobiel, general manager; Ross Phillips, chemist. The company own and operate the patents of I. L. Roberts (U. S. Patents 673,452 and 673,453) for electrolytic apparatus and connections. No further details of the working of this company are available.

### A. L. ROSSI.

This veteran pioneer in the field of ferro-titanium is still reducing titanium ores on a semi commercial scale at Niagara Falls. His 200 horse-power furnace is situated in a stone building between the plants of the Electrical Lead Reduction Co. and the Acheson Graphite Co. Here he is reducing ilmenite, titanic iron ore containing 65 per cent. of ferric oxide and 35 per cent. of titanic acid, in the electric furnace, producing at will a high ferro-titanium, or, by using iron as flux, an almost pure cast iron. He makes two grades of ferro-titanium, one with 4 per cent. of titanium, for use in cast-iron foundry work, and the other with 10 per cent. titanium, for use in steel. The 4 to 5 per cent. alloy melts easily at the heat of a foundry cupola, or of ordinary coal fuel, and is particularly valuable for making a high quality of car wheel castings. The 10 per cent. alloy melts at the heat of a steel-melting furnace and is claimed by Mr. Rossi to impart wonderful virtues to steel.

### THE NATIONAL ELECTROLYTIC CO.

The plant of this company is below the falls, and they receive direct current of 2,000 horse-power from the power

FIG. 14.—THE NATIONAL ELECTROLYTIC CO.

house about 500 feet away. The plant at Niagara manufactures potassium chlorate under the patents of W. T. Gibbs, viz. U. S. Patent 665,426 and 665,427, of January 8, 1901, for the manufacture of chlorates, and U. S. Patent 665,679, of same date, for an electrolytic apparatus.

The process used consists in principle in the electrolysis of a solution of potassium chloride, using a copper or iron cathode and a platinum anode, the electrodes being but a very small distance apart, using a high current density, a temperature above 40° C. and no porous partition. Under these circumstances, chlorate is abundantly formed, passes out of the apparatus before the solution contains a high percentage of it and is crystallized out by cooling the solution. The efficiency of the operation is a datum which the company do not desire to publish, their first experiments were said to have yielded 55 to 60 per cent. of the theoretical amount of chlorate, and their present practice is somewhere nearer to 70 per cent. efficiency.

The apparatus employed consists of rectangular wooden frames, 18 by 20 inches inside, alternating with lead plates, placed together in a frame like a filter press, with rubber gaskets between. One side of the ¼ inch gaskets is against the iron or lead plate, the other against the copper or iron cathodes. The wooden frames being covered with lead, to furnish electrical connection from cathodes to anodes. The anodes are platinum foil supported on the lead or iron plates. They are unattacked. The cathodes were originally of iron gauze, covered with oxide of copper, it being found that the hydrogen there set free would reduce these oxides and thus depolarize the electrode and diminish the potential necessary for running the cell. Such cathodes were not satisfactory and have been replaced by bare copper. They are in the form of rods, forming a grid with transverse strengtheners, and with insulating rods to keep them from touching the anodes from

a little less than 1-64 of an inch distant. The distance of these 2 inches between the pairs of electrodes allows a considerable volume of solution to present itself for electrolysis, and, being well circulated, obviates the difficulties which would otherwise arise from having the electrodes within 1-64 of an inch of each other. The open, grid-like formation of the electrodes renders this scheme effective. Solution of potassium chloride runs into each cell continuously, at the rate of about one gallon for each thirty minutes, at a temperature of 20° C., and its flow is so regulated that the temperature of the effluent streams above 40° C. and averages 70° C. The chlorate formation takes place properly as the temperature keeps above 40° C., being interfered with greatly by impurities in the solution, such as insoluble or colloidal precipitates.

Any number of such cells may be put into one frame, in form like a filter press, with rubber gaskets between and screwed up water tight. The current is then passed through them in series, with a current of 1,650 ampères, giving a current density at the anode of 500 ampères per square foot. Since the conversion of chloride into chlorate absorbs 1.4 volts in the decomposition, about one-third of the energy of the current is used up in chemical work, while two-thirds are converted into heat, sufficient, theoretically, to raise the temperature of the cell 5° C. per minute, if it were not kept cool by the circulation of the electrolyte. The issuing stream is from 65° to 70° C., and foamy from evolving hydrogen. A cell of this kind is said by Kershaw (article in the *London Electrician*) to have been patented to Gibbs and Franchot in 1893, to have been experimented with in 1895 and to have given, on a two months' trial, 4,386 pounds of chlorate per horse-power per day, which is an efficiency of 67 per cent.

The manufacture of potassium chlorate is one of the oldest of electrochemical manufactures, but an inspection of the plant of this company certainly justifies the statement that their arrangement of plant and manner of working are not excelled, and probably not equaled by any other works in this line of business.

THE ATMOSPHERIC PRODUCTS CO.

This company are an offshoot from the Ampère Electrochemical Co. They were incorporated early in 1902, with a capital stock of $1,000,000. Chas. S. Bradley is president and D. Ross Lovejoy, electrician. The process was evolved by Bradley and Lovejoy, and has been worked out in detail mostly by Mr. Lovejoy. The U. S. Patent is allowed, but not yet issued; the English Patent is 8,230, of June 8, 1901. The patent is for

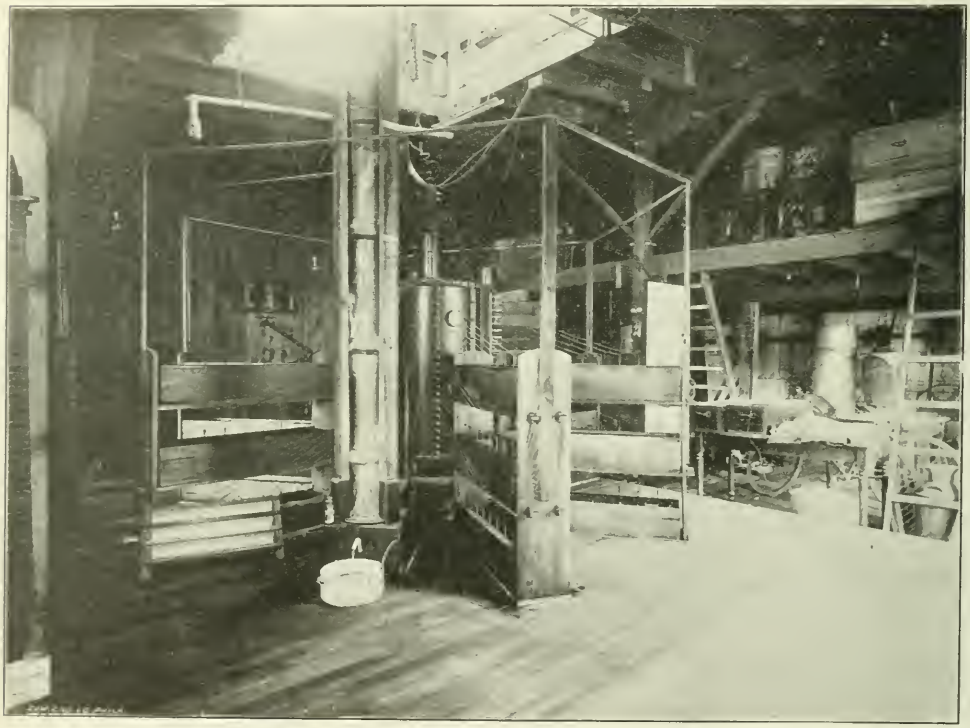


FIG. 15.—NITRIFICATION CHAMBER AND COLLECTION TOWER. THE ATMOSPHERIC PRODUCTS CO.

a manner of producing nitrogen compounds from atmospheric nitrogen, and points out that whereas the silent electric discharge and the spark or disruptive discharge can cause nitrogen and oxygen gases to combine, they have very little capacity in this respect, which is also the case with the electric arc, as ordinarily used. To obtain efficiency, it is necessary to use an arc, divided up into such small, thin, flat subdivisions as to present a large surface for a small amount of energy; the thinner the arc is the greater is its efficiency up to the point where it breaks. It is necessary, therefore, to greatly subdivide the current, to arrange the arc circuits in parallel and to provide against short circuiting.

The experimental apparatus of this company is installed at the works of the Ampère Electrochemical Co. They use a 45 kilowatt generator, ordinarily delivering 0.75 ampères direct current at a potential of 8,000 volts, but capable of giving sev-

eral ampères at as much as 15,000 volts. This remarkable generator was built by the Wayne Electric Co. The current supplies 138 arc contacts, each of which is made and broken 50 times per second, giving to each arc some 0.005 ampère. The arcs are all sprung successively, 6,000 per second in the apparatus, each arc lasting about 1-20,000 of a second, and thus giving practically a steady load to the machine. As each arc tends, the moments it is formed, to increase suddenly in

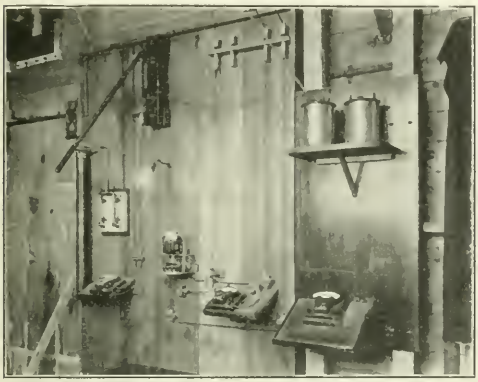


FIG. 16. SWITCHBOARD OF ELECTRICAL MEASURING INSTRUMENTS. THE ATMOSPHERIC PRODUCTS CO.

volume, the short circuiting which this would produce is retarded by placing inductance coils or resistances in series with the arcs. These are so calculated that during about 1-40,000 of a second they impede the flow of current, therefore preventing too high an ampérage flowing, and during the succeeding 1-40,000 second, while the arc is being drawn out and is about to break, it sends an impulse which increases the flow and so prolongs the arc. Using 8,000 volts, with an

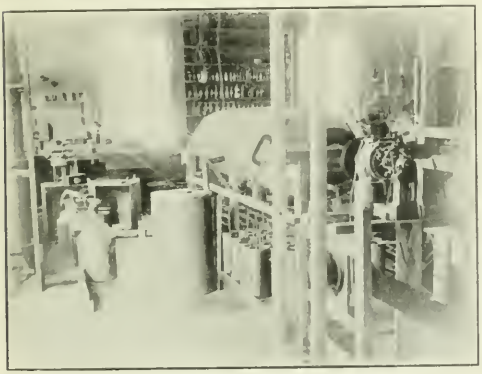


FIG. 17 EARLY EXPERIMENTAL APPARATUS. THE ATMOSPHERIC PRODUCTS CO.

average current of 1-200 of an ampère to an arc, the arcs are drawn out 4 to 6 inches. By keeping a constant flow of air into the apparatus, the per cent. of combined products in the issuing air is only 2 to 3 per cent., and much less by dissociation is thus avoided by keeping down the concentration of nitric oxides. The patent claims are for "exposure of a mixture of nitrogen and oxygen to the action of an electric arc, and renewing the mixture so as to prevent dissociation."

The apparatus used at Niagara is 5 feet high by 4 feet in diameter, circular, of iron and has in the sides six rows of inlet wires, 23 in each row, the wires entering being well insulated by a porcelain sleeve and terminating in a short

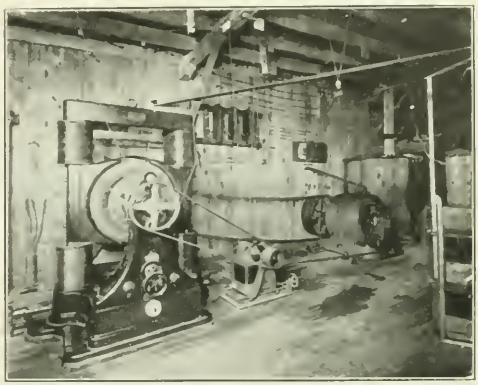


FIG. 18. MOTOR AND 10,000-VOLT DYNAMO, WITH EXCITER. THE ATMOSPHERIC PRODUCTS CO.

platinum wire, ¼ inch long, turned downwards. In the center of the apparatus is a vertical shaft, containing a series of 23 radial arms, each corresponding to the 23 rows of points.

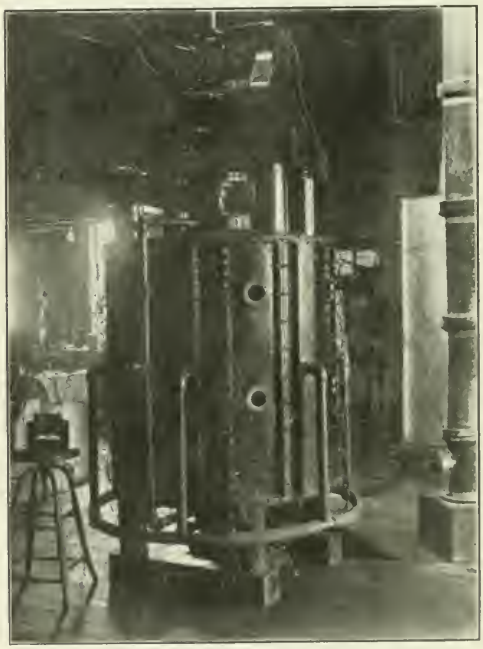


FIG. 19.—CHAMBER WITH INDUCTANCE COILS DISCONNECTED. THE ATMOSPHERIC PRODUCTS CO.

exterior wires, and there being six radial arms in each plane. The radial arms are tipped with short platinum wires, which come within 1-25 of an inch (1 millimeter) of the platinum wires of the opposite poles. As the two points approach, a

spark jump about ½ inch to meet the approaching point, and then the arc is drawn out 4 to 6 inches by the retreating point. Each arc has in series a resistance coil, 5 inches in diameter by 12 inches long, immersed in oil, and containing several thousand turns of fine wire. The central shaft is run at 500 revolutions per minute, and takes a little over 1 horse power; run at 1,000 revolutions per minute, it takes some 5 horse-power. The output is represented by one pound of theoretical HNO per 7 horse power per hour of electric current used.

Air can be used in the apparatus, first carefully dried to

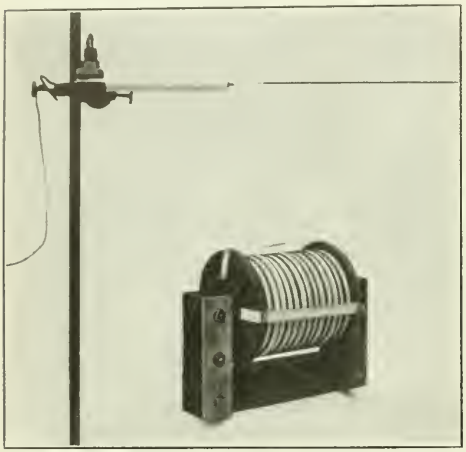


FIG. 20.—INDUCTANCE COIL AND A PAIR OF ELECTRODES. THE ATMOSPHERIC PRODUCTS CO.

avoid formation of acid in the apparatus and consequent corrosion of the metallic parts. The inside of the apparatus is protected by a coating of asphalt varnish and glass peepholes are provided, permitting inspection of the interior. A mixture containing equal parts of oxygen and nitrogen works better than air, giving a higher return for the current used. This is quite natural, since air contains 1 volume of oxygen to about 4 of nitrogen, whereas the gases formed contain 1 volume of oxygen to 1½ or 2 volumes of nitrogen. Air can be enriched to 50 per cent. oxygen in Linde machines at the rate of 1 cubic meter per horse power per hour. The efficiency obtained increases as the ampère per arc decreases, until the arc degenerates into a spark. The gases are renewed at the rate of 3 to 4 cubic feet per minute, in order that the issuing gases may not contain over 3 per cent. of nitrogen oxides. The temperature in the generator is thus kept at about 80° C. The issuing gases pass into an iron reservoir, 2 feet in diameter by 10 feet high, where they have a chance to still further combine and thence pass into a scrubbing tower to condense the gases produced. This is an earthenware pipe, 9 inches in diameter by 25 feet high, filled with coke, over which trickles water if acid is desired, or a solution of caustic alkali, if alkaline nitrate is wished. The latter is the more convenient for experimental work, as the amount of time necessary to neutralize a given quantity of alkali gives an accurate measure of the output of the apparatus. In commercial practice, water towers will be used to obtain nitric acid, for which there is a market for 100,000 tons a year in the United States, while Lunge's scrubber, supplied with milk of lime, will be used to produce calcium nitrate, for fertilizing purposes. This is a cheaper way of getting the nitrogen onto the fields than using soda, because lime costs only $1.50 per ton and is needed also by many soils.

The process has worked so successfully and promisingly on this experimental scale, that the company will engage in the commercial manufacture as soon as the power company have current to supply. It is proposed to begin with 2,000 horse-power. Since the space required for apparatus will be large, a large tract of ground, permitting future extensions, is to be acquired. Since the cost of apparatus will also be heavy, the company are already building a machine shop, 50 by 150 feet, two stories high, near to the Pittsburg Reduction Co's plant, where they will build their own apparatus. To supply all the nitric acid used in the United States would require a plant of some 150,000 horse-power, covering many acres of floor space, but such is one of the possible future developments of this process.

### THE UNION CARBIDE CO.

Calcium carbide was first made industrially by Mr. Willson, at the Willson Aluminum Works, at Spray, N. C., in 1891. Since then its manufacture has become one of the largest of the electrochemical industries, it being estimated that the total capacity of calcium carbide works in the world is 250,000 horse-power, equal to producing some 300,000 tons per year, one-fifth of which are in America.

Mr. Willson was trying to reduce lime by carbon, in the electric furnace, in order to produce calcium, with which he expected to be able to reduce aluminum. The accidental discovery that the product gave off an inflammable gas (acetylene) when brought in contact with water, and the subsequent recognition of the calcium carbide by analysis and its industrial production on a very large scale, sounds more like an interesting tale than a solid, commercial fact. It is, however, a fact that the manufacture of calcium carbide has done more to bring the electric furnace and electric methods into industrial prominence, especially in Europe, than any other electrochemical operation. In Europe, in fact, the carbide industry has been woefully overdone, Italy alone possessing enough *carbide* plants to supply the whole of Europe.

Mr. Willson's small beginnings gave place to the formation of the Union Carbide Co., which controls almost all the production in America. The works at Niagara Falls are under the management of Mr. Price, who was associated with Mr. Willson in his first experiments. The patents to Mr. Willson are U. S. Patents 541,137 and 541,138, of 1895, and 563,527, of 1896; to Mr. Price 572,312 and 572,467, of 1896, and 583,936, of

FIG. 21.—UNION CARBIDE CO.

1897. It is said that the furnaces used are covered also by the patents of Hoovey on a rotating furnace, English Patent 22,521, of 1897, although the circular furnace is said to be originally the invention of Prof. F. B. Crocker, New York.

The works are situated nearly one and a half miles from the power house, above the falls, and are supplied through a conduit with 5,000 horse-power of alternating current at 2,250 volts. The works have the option of taking up to 20,000 horse-power when they want it and the power company are

able to supply it, but the average power which has been used has been close to 5,000 horse-power. The buildings cover 200 by 880 feet of ground, the stock room being three stories in height and ten furnaces are now in operation.

The furnaces are of iron and circular, with a recessed rim, on top of which are bolted segmental wings, 24 inches deep. In the space thus created, the two carbons dip on top of the wheel, and melt the charge of lime and carbon there fed to them. The whole furnace revolves very slowly, about once in twenty-four hours, on trunnions, so that the fluid carbide resulting from the action of the arc is slowly taken out of the field and solidifies in cakes 6 to 9 inches thick, which is taken off the wheel, comparatively cold, at the lower side. The carbons are 6 inches in diameter and are kept about 9 inches apart. The furnace is 8 feet in diameter altogether, 3 feet wide and each takes 3,500 amperes at 110 volts, or 500 horse-power. The output per furnace is about two tons per day.

The materials charged are mixed burnt lime and ground coke, in the proportions of one ton of lime and three quarters of a ton of coke to produce one ton of carbide, the chemical reaction being

$$CaO + C_3 = CaC_2 + CO.$$

The temperature of formation of calcium carbide is above that of ordinary combustible-heated furnaces, but not very high in the range of electric furnace work; it is decidedly below that needed for graphitizing carbon or even for producing carborundum. If we consider the energy required to produce a ton of calcium carbide in these furnaces as 6,000 horse-power hours, we can calculate that of the total energy of the current about 45 per cent. is needed to heat the substances to the temperature of carbide formation, 40 per cent. is absorbed in the chemical reactions taking place and 15 per cent is lost by radiation during the heating (exclusive of heat in hot carbide after removal from the arc).

The ten 500 horse-power furnaces in operation will, therefore, produce 20 tons of carbide daily, using up 20 tons of lime and 15 tons of coke. The carbide, when used, furnishes theoretically 5.5 cubic feet of acetylene per pound, or actually some 5.25 cubic feet, which is 10,500 cubic feet per ton of carbide, and the 20 tons would be equal to 210,000 cubic feet, equal in illuminating power to some 2,040,000 cubic feet of ordinary illuminating gas in illuminating power. The reaction producing acetylene is

$$\underset{64}{CaC_2} + \underset{36}{H_2O} = \underset{56}{CaO} + \underset{26}{C_2H_2}$$

and since $C_2H_2$ represents one molecular volume (22.22) of gas, we may say that 64 ounces of carbide produces theoretically 22.22 cubic feet of acetylene and requiring 18 ounces of water.

## THE INFLUENCE OF DIFFUSION IN THE ELECTROLYSIS OF SODIUM CHLORIDE.

By CLINTON PAUL TOWNSEND.

THE electrolytic decomposition of sodium chloride in aqueous solution presents chemical problems of no small degree of complexity. If a body of the dissolved salt be decomposed with insoluble anodes and inert cathodes, the immediate products are chlorine and sodium, the former soluble in brine, the latter oxidized thereby, each product capable of uniting with the other, with the solvent, and with the secondary products formed by reaction of the other with the solvent. Around the anode is formed a saturated solution of chlorine, evolving the excess of gas; from the cathode hydrogen escapes, carrying upward with it and distributing through the solution the sodium hydroxide resulting from the oxidation of the metal. The sodium hydroxide and the chlorine diffuse throughout the solution, and in the regions of contact unite to form sodium hypochlorite, which in its turn diffuses toward both electrodes. At the anode it is in part oxidized to sodium chlorate, and at the cathode is quickly reduced to chloride; at both electrodes it undergoes electrolysis, the cathode products, primary and secondary, being sodium and sodium hydrate, and those of the anode hypochlorous acid and oxygen. Furthermore, not the hypochlorite only, but the chlorate and the hydroxid submit readily to electrolysis, adding to the complexity of the anode products.

Of these several products, the hydroxid, hypochlorite and chlorate of sodium, and the chlorine, are commercial articles, representing enormous aggregate values in the industrial world; still another compound, sodium perchlorate, has been produced for a hundred years past in the laboratory by electrolytic methods, but is seldom encountered in cells operating upon chloride solutions. For the production of hypochlorites and of chlorates, such disposition of parts is now employed as will facilitate the immediate combination of the products formed at the respective electrodes. For the production of caustic and of chlorine, however, the essential point is to maintain these products apart; to permit the accumulation of the caustic to a reasonable concentration, yet to prevent, so far as may be, its movement by diffusion to or into the anode solution. And surely no more interesting problem was ever offered to the experimenter. The purpose of this paper is to outline briefly, and in their broader aspects, the several lines of attack which have been opened toward a solution of the problem.

If a diaphragm be interposed between the electrodes, the course of the reactions is as above specified, for the phenomena depend largely upon diffusion, which no diaphragm permeable to the current can prevent. Yet a diaphragm modifies to a considerable extent the composition of the final products, for the convection effects, like in kind and at least equal in quantity to those due to diffusion, may be measurably overcome. The diaphragm operates, moreover, to limit the region of contact between the anode and cathode solutions, a fact which forms the basis of some very interesting and quite practicable methods for the maintenance of dilute solutions in a state of reasonable purity, by withdrawing at this point those portions of the solution which have become impure through combination.

The diaphragm may be in contact with one or both electrodes, or at a distance from either; in the latter case the cathode products are necessarily permitted to remain for long periods in contact, through the diaphragm, with those of the anode. Under these conditions diffusion is unchecked, and for this reason no cell of this type has ever attained any considerable measure of commercial success. If the cathode be moved into contact with the diaphragm, and given such open structure as will permit the ready escape through it of the products of the electrolysis, diffusion proceeds as before, but the electrical resistance is so far reduced that the line between failure and commercial success is crossed, to this type belong the earliest of the operative electrolytic processes for the production of caustic from brine. In such cells the fact of diffusion, and of losses attendant thereon, is frankly admitted, and the resulting hypochlorous acid is usually decomposed in the anode compartment by the regulated addition of hydrochloric acid, often obtained by the direct combustion of portions of the hydrogen and chlorine from the respective electrodes.

In such cells, however, the cathode compartment may be drained, and an increased efficiency is thereby secured. The cathode being in contact with the saturated diaphragm, a thoroughly efficient electrical contact is maintained, and being foraminous it permits the discharge by gravity of the excess of the percolating solution. Its capacity for retaining the caustic solution is, however, far from negligable, and in proportion as it retains such solution it fails to accomplish its proper function of a surface of discharge for the cathode products. The form of the cathode, whether a wire net, a perforated plate, a ribbed plate or a sponge, is thus an essential

pose to be determined by an experimental study of its retentive capacity. The claim more recently advanced in favor of a "spongy" or retentive cathode is that the electrolysis proceeds or continues within its interstices; admitting, however, that there exist within the body of the metal such points of potential difference with relation to the anode as will determine therein an electrolytic effect, it will require the clearest of experimental evidence to prove that the electrolyte is sodium chloride and not the more easily decomposable hydrate.

If a compact, spongy or porous, as distinguished from an open cathode, be used, the non conducting diaphragm is no longer essential to operativeness, for the cathode will itself restrain the flow of the electrolyte and permit the production of caustic of fair concentration. The retention of the diaphragm becomes then a question of expediency, its chief function being to guard the cathode from clogging by deposition therein of the hydrated oxides insoluble in the electrolyte. Seemingly, its use is advantageous, for commercial success has not been attained in its absence.

In diaphragmed cells of whatever type, a considerable apparent increase in efficiency may be secured by converting the caustic as formed into a compound less soluble in the electrolyte, more stable as regards the current or possessing a lower diffusion rate If such compound represented also an increased value as compared with the caustic and the acid radical which enter into its composition, the increase in efficiency would be real, but, unfortunately, such is not the case, and the method represents in all cases a reduction of values, and can, therefore, be regarded only as an economic retrogression. This, of course, does not mean that it may not also present a margin of profit, simply that the margin of profit is less than if the cell were so constructed as to be capable of yielding the caustic alkali. As types of auxiliary reactions of this character may be mentioned the carbonating of the cathode lyes by carbon dioxide, with the formation of the normal or acid salt; the addition of carbonates of magnesium or of zinc to form double salts; the addition of nitric, manganic and chromic acids; the employment of such solid depolarizers as the metallic sulphates, phosphates, sulphides, etc., and the use of metallic salts in solution as liquid depolarizers, examples being auric chloride, sodium plumbate and the sulphates of iron, copper and zinc. Depolarizing cathodes have also been employed; readily reducible oxides or sulphides which yield their metalloid to the liberated hydrogen. If oxides be used their reduction serves, of course, to dilute the caustic, and if sulphides, the cathode product is no longer the hydrate, but the sulphide of the alkali metal.

The cells which operate on the gravity principle, like those of the diaphragm type, are powerless to overcome the evils of diffusion. In these dependence is placed on the differences in specific gravity between a saturated solution of the salt, and the caustic and chlorine resulting from its decomposition; some devices of quite surprising efficiency have been developed here and abroad, but if it be borne in mind that the rate of diffusion is a function of the concentration of the diffusing solution, and that the amount of diffusion is a function of the time during which given solutions remain in contact, it will be readily understood that such cells necessarily yield weak caustic.

So far as concerns the yield of caustic, the use of insoluble anodes is not material, and it has been attempted to reduce the potential difference between the electrodes and to increase the total value of the final products, by the employment of depolarizing anodes. Iron, zinc, tin, lead and copper have been so used, the salts formed often being precipitated in the anode compartment, or in an external portion of the circulating system, by appropriate reagents, *e. g.*, the lead by regulated addition of soluble chromates, to prevent diffusion toward the cathode. Crude metals, as the alloys of copper and nickel, have been favorite anodes for use in these relations, and the solutions obtained are usually further treated by electrolytic methods. No process of this character has passed the experimental stage.

Or instead of using a depolarizing anode, the same result may be accomplished by adding to the anode compartment solutions to be chlorinated, or such ores as it is desired to submit to the solvent action of the anolyte. Such methods have, however, introduced such further and unexpected complications as have interfered with the smooth working of the cell.

In addition to the foregoing, two other distinctive methods have been proposed, elaborated through protean forms, and passed into commercial use. As has been pointed out, the real difficulty of the problem lies in overcoming the rapid diffusion of the hydrate through the aqueous solution, and the conception that this might be accomplished by doing away with both solution and hydrate was a basic one. New difficulties arose, however, in the attempt to produce sodium and chlorine directly from the fused chloride; hypothetical "subchlorides," formed at the high temperatures, diffuse as rapidly and with as evil effect as the hypochlorites of the aqueous solution, and for the production of the metal, compounds of lower-melting point, the hydrate and nitrate, have displaced the chloride. The employment of a liquid metal cathode to absorb the sodium as separated has proven, however, a stepping stone to success in the production of the hydrate.

As in the case of aqueous solutions the difficulty to be overcome in cells of the last-mentioned type has arisen from the diffusion into the bath of the cathode product, or, more properly, of the reduction products formed by reaction between the cation and the electrolyte; for the liberated sodium shows no tendency to distribute itself evenly through the body of the molten lead, but crusts it over in a light and rich alloy of intense chemical activity.

The problem has been doubly solved. A supplemental anode of lead, through which a fraction of the total current is shunted, has been used to determine the conjoint deposition of sodium and lead in such proportions as may be desired for the alloy. This method necessarily operates at low efficiency, not only because some 12 per cent. of the current is diverted for the solution of the lead, but because the lead chloride of the bath reacts readily with the separated sodium, the reconstituted sodium chloride representing a direct and serious loss. The second and more rational method consists in preventing the accumulation of the light metal by maintaining the cathode of molten lead in rapid circulation between the region of electrolytic activity and a separate denuding chamber, wherein the sodium is oxidized and the resulting hydrate permitted to stratify. Diffusion is here overcome by reducing the concentration of the diffusing element; the advantage is such as would be obtained in the aqueous method were it possible to remove the hydrate from the cathode at the instant of its formation. Under this mode of operation current efficiencies are high, and such concentration of plant as is indicated by the passage of a current of 19 ampères from each square inch of active anode surface offers alluring economic possibilities. All fused electrolyte methods labor, however, under the disadvantage that the separation of a gram of sodium therein, under conditions of theoretical efficiency, represents the expenditure of nearly double the energy of the same reaction occurring in aqueous solution, under conditions which permit the oxidation of the metal.

The mercury cathode method for the conversion of aqueous chloride into caustic is the precise analogue of the foregoing, and commercially is the successful method of the day. The analogy between those fused and aqueous methods which depend upon the absorption of the cation by a liquid metal is more than superficial, for not only are the methods similar in the form which they have finally taken, but in their historical development they have followed the same course. In the early work the mercury cathode was quiescent, and the objects of the electrolysis were defeated by the combination of the metal

of the light surface alloy with the electrolyte. Thereafter, the necessity for quick dissemination, or, better, for quick denudation, was recognized, and the history of recent construction in cells of this type is largely concerned with the provision of means for effecting the interchange of amalgam between the decomposing and oxidizing compartments. One additional idea has been recently introduced: the conception that means other than mechanical may control the diffusion of the sodium through the mercury. The phenomena of surface tension promise to afford a method of transmitting the alkali metal positively and rapidly through a body of mercury acting as a partition between brine and caustic solutions.

## ELECTROCHEMICAL THEORIES ILLUSTRATED BY EXAMPLES FROM PRACTICE—I.

IN this serial an attempt will be made to illustrate and explain the modern theories of electrochemical science by examples from practice, and to bring electrochemical science within the reach of the practical man. Each article will be complete in itself. In the first article we will discuss a fundamental principle of the design of galvanic cells. The following experiment, which has been described by Prof. W. Ostwald, is very instructive. Well amalgamated zinc does not dissolve in a solution of sulphuric acid. If, however, an amalgamated zinc rod in contact with a platinum wire is placed into a solution of sulphuric acid, then the zinc dissolves at once with a simultaneous development of hydrogen. Let us begin with a neutral salt solution and suspend in it a zinc rod and a platinum wire, which are in contact at one point outside of the solution; no zinc dissolves; as soon as we add free sulphuric acid the zinc begins to dissolve. Let us change the conditions slightly. Take a vessel with two compartments, which are separated from one another by a porous partition; the zinc rod is placed in the one compartment, the platinum wire in the other; the zinc and platinum are in contact outside of the vessel. Both compartments are filled with a neutral salt solution. We now wish to start the dissolution of the zinc. For this purpose we have to add free sulphuric acid to the neutral solution. Now the question arises: to which compartment have we to add the acid? At the first glance it would seem that as we wish to dissolve the zinc, we have to pour the acid into the compartment containing the zinc, but this would be wrong. By experiment we find that in order to get a lasting dissolution of zinc, we must add the acid to the compartment containing the platinum wire; the zinc dissolves in the one compartment, and at the other compartment hydrogen is developed at the platinum wire.

The explanation of the fact will give us a general principle for the design of galvanic cells. Indeed in our case, we have electrochemical action. If the ends of the zinc rod and of the platinum wire outside of the vessel are not connected directly together, but through a galvanometer, we see that a continuous current flows through the system, from the zinc to the platinum in the solution. We have here a change of chemical energy into electrical energy; in other words, we have a galvanic cell. The problem is, therefore: why is this cell active only if the acid is added to the solution at the platinum side, and not at the zinc side? The discussion of this problem will first lead us to point out the characteristic property, which distinguishes those chemical equations which can represent electrochemical action, from those which cannot represent electrochemical action. Afterwards, we will state a simple reaction which can represent electrochemical action, and will discuss the particular conditions under which, in this reaction, chemical energy is changed into useful electrical energy. We will begin with some general remarks on chemical equations.

The most concise and exact way of describing a chemical process is by means of a chemical equation. That chemical equations have a simple form, is a result of the experimental fact that elementary substances combine in constant multiple proportions. Thus, the neutralization of an acid by a base is represented by an equation like

$$HNO_3 + KOH = KNO_3 + H_2O, \qquad (1)$$

which equation states that one gram molecule $HNO_3$ (63.05 gram), and one gram molecule KOH (56.10 gram), are changed into one gram molecule $KNO_3$ (101.10 gram), and one gram molecule $H_2O$ (18.02 gram). The solution of a metal in an acid is represented by an equation like

$$Zn + H_2SO_4 = ZnSO_4 + H_2 \qquad (2)$$

which equation states that one gram molecule Zn (65.4 gram) and one gram molecule $H_2SO_4$ (98.08 gram) give one gram molecule $ZnSO_4$ (161.46 gram) and two gram atoms H (2.02 gram). This is the way in which the chemical equations are generally understood by chemists; the transformation of matter only is considered, and the combining proportions of the different materials, involved in this transformation, are given by the chemical equation.

If, however, a chemical process is considered from a broader and wider point of view, then there is not only a transformation of matter, but at the same time always a transformation of energy. If the changes of energy are taken into account, there do not exist any chemical processes pure and simple; that means: any chemical process in a system of reacting bodies (which system is supposed to be separated from the outside) represents either a gain or a loss of chemical energy in the system, and thus, according to the principle of conservation of energy, must involve a loss or a gain of some other kind of energy. The principal forms of energy into which chemical energy is changed in practice, are heat and electrical energy; one speaks, therefore, of thermochemical and of electrochemical processes.

The energy changes can also be easily represented by equations, when an additional meaning is given to the ordinary chemical symbols. Thus, $HNO_3$ represents, as before, a certain mass; if we measure all the masses in gram molecules, it represents 63.05 gram; but we now assume that it also represents a certain energy, namely, the intrinsic chemical energy stored up in 63.05 gram of the chemical compound $HNO_3$. We assume that the intrinsic energy of all the elements in the free state is zero; then the intrinsic chemical energy stored up in 63.05 gram $HNO_3$ represents the energy corresponding to the change of 1.01 gram H, 14.04 gram N, and 48 gram O, into 63.05 gram $HNO_3$. If we understand the chemical symbols in this way, the ordinary chemical equations, like (1) and (2), do not balance any more; because the chemical energy stored up in the materials at the beginning of the reaction, does not equal the chemical energy stored up in the materials at the end of the reaction. Thus, we know that when the processes (1) and (2) take place from the left side to the right side, both processes evolve energy; and if, according to our assumption, the masses of the chemical symbols represent gram molecules, then the energy evolved by each process has a certain distinct numerical value which has been determined by experiment. Energy can be measured in gram calories, watt seconds, gram centimeters, or any other unit which one may choose. The energy evolved or absorbed by a certain chemical process is generally given in gram calories, as it is determined from thermochemical measurements. The equation (1) then assumes the form

$$HNO_3 + KOH = KNO_3 + H_2O + 13{,}800 \text{ cal}., \qquad (3)$$

i. e., when in an aqueous solution one gram molecule $HNO_3$ and one gram molecule KOH change into one gram molecule $KNO_3$ and one gram molecule $H_2O$, energy is evolved equal to 13,800 gram calories. Equation (2) gets the form

$$Zn + H_2SO_4 = ZnSO_4 + H_2 + 37{,}900 \text{ cal}.,$$

i. e., when one gram molecule $H_2SO_4$ in aqueous solution dissolves one gram atom Zn, to form one gram molecule $ZnSO_4$ and 2 gram atoms H, energy is evolved equal to 37,900 gr. cal.

Instead of giving the energy value in gram calories, we

may state it, we give it in watt seconds, as there is a constant relation between both units:

1 watt second = 0.241 gram calorie,
1 gram calorie = 4.155 watt seconds,

so that it is easy to go over from gram calories to watt seconds. But the formal change from the heat unit of energy to the electrical unit is evidently useful and judicious only if we know that the chemical equation represents an electrochemical action.

Now the important question naturally arises: can any chemical equation represent an electrochemical action? It will be shown that this question must be answered in the negative. For instance, it will be shown that of the above chemical reactions, both of which evolve energy—equation (1) can never by itself represent an electrochemical action, while equation (2) can represent an electrochemical action. What, then, is the characteristic feature of those chemical equations which can represent electrochemical action?

We know that whenever electrochemical action takes place either in a cell into which current is sent from the outside, or in a galvanic cell, which gives out current—the strictly electrochemical action takes place at the electrodes. We may say in general that we have always reduction at the cathode and oxidation or perduction at the anode. The term "perduction" has recently been suggested by J. W. Richards, instead of oxidation, because the latter term would seem to indicate a combination with oxygen, which is not always the case when we have perduction. The characteristic feature of reduction and oxidation, or perduction, is that there is a change of valency. The amount of material reduced at the cathode and the amount of material oxidized or perduced at the anode are directly given by Faraday's law; and as the latter is the fundamental law of electrochemical action it is evident that there must be reduction and oxidation, whenever there is electrochemical action. In the experiment described above, zinc goes into the solution; from the uncombined state it goes over into the sulphate, it gains "bonds," in other words it is "oxidized," or perduced. At the other end, at the platinum wire, hydrogen leaves the solution; from the state of combination with $SO_4$ it goes over into the uncombined gaseous state, it loses "bonds," in other words, it is reduced. This example will show what is meant here with reduction and oxidation; a more detailed discussion of this matter will be given in a future article. For the present it is sufficient to state that only those chemical equations can represent electrochemical action which represent oxidation and reduction. This is the case for equation (2), as just explained, but it is not the case for equation (1). In equation (1) H and K simply exchange their places, but *without any change of valency*. For this reason it is evident that under no circumstances equation (1) by itself can represent electrochemical action; of course, the process represented by (1) may take place as *part* of the whole process occurring in an electrochemical system, but it can never represent the total electrochemical process.

Now take the reaction of equation (2). We know it can represent electrochemical action. But this does not mean that under all circumstances we get the chemical energy lost during this reaction in the form of useful electrical energy. For instance, when we put unamalgamated zinc into sulphuric acid, equation (2) again represents the action, but in this case we get heat instead of electrical energy. It is evident that to change the chemical energy into useful electrical energy, we must arrange our system properly; and this leads us back to Ostwald's experiment described above. We saw that in the arrangement described it was necessary to add the acid to the compartment at the platinum wire. The reason will now become clear: we always must arrange our system so that the substance to be reduced is at the one electrode and the substance to be oxidized is at the other electrode. If we bring both substances together directly, the chemical energy is changed into heat. If we want to get useful electrical energy, we have to keep them separated, and have to place the substance to be reduced at the one electrode, and the substance to be oxidized at the other electrode. That is why Ostwald speaks of "chemical action into the distance." In our case, while the cell gives out current, zinc is dissolved, *i. e.*, oxidized, and hydrogen is reduced from its combination in $H_2SO_4$ to free hydrogen. Hence the sulphuric acid must be placed at the platinum.

This principle appears now to be self-evident, but it has not always been so, and many inventors, in designing batteries, have made the mistake of bringing the substances to be oxidized and to be reduced directly together; the result is always in such cases that a strong chemical action occurs, but that heat is developed instead of electrical energy.

We will briefly illustrate our principle by a few examples. In the Daniell cell we have the reaction

$$Zn + CuSO_4 = ZnSO_4 + Cu;$$

Zn is oxidized, Cu is reduced. The Zn and $CuSO_4$ must be kept separately; this is done by using a double fluid cell, the Zn being placed in a solution of $ZnSO_4$ or $H_2SO_4$.

In the Bunsen cell, with Zn in $H_2SO_4$, and C in $HNO_3$, Zn is oxidized and N is reduced; hence the Zn and $HNO_3$ are kept separately; one of the possible reactions is

$$3\,Zn + 3\,H_2SO_4 + 2\,HNO_3 = 3\,ZnSO_4 + 2\,NO + 4\,H_2O.$$

In the same way, in the chromic acid battery we must keep the chromium solution away from the zinc.

In the lead accumulator the action is

$$Pb + 2\,H_2SO_4 + PbO_2 = 2\,PbSO_4 + 2\,H_2O,$$

the spongy lead at the one side being oxidized to lead sulphate, and the lead peroxide being reduced to lead sulphate at the other side.

In the new Edison battery we have the reaction

$$NiO_2 + Fe = NiO + FeO,$$

the nickel being reduced and the iron oxidized.

Everything in Ostwald's experiment, which seemed peculiar, can now be explained. Amalgamated zinc does not dissolve in a solution of sulphuric acid; it represents a single electrode, and this is no electrochemical system. But if this zinc is in contact with a platinum wire, we have an electrochemical system, we have a short-circuited cell, hence the zinc will dissolve. If we use the vessel with the two compartments separated by a porous partition, then one compartment will have to represent the anodic compartment, and the other the cathodic compartment; in the former we have to place the zinc, which is to be oxidized, and in the latter the acid, as the hydrogen is to be reduced. The neutral salt solution around the zinc furnishes the ionic mechanism by which the "chemical action into the distance," *i. e.*, the reduction and oxidation at both ends, is made possible.

## GRAPHITE ELECTRODES IN ELECTROLYTIC WORK.

By C. L. Collins, 2D.

THE relative value of graphite and other forms of electrode material in the various lines of electrolytic work has already been discussed thoroughly, and the results of numerous comparative tests published. These results, obtained both in experimental test and actual practical work, may be briefly summarized as follows:

In the electrolytic decomposition of chloride solutions, in the manufacture of chlorine and caustic alkalies, in the chlorination of gold ores, in the recovery of nickel, zinc, etc., graphite electrodes used as anodes possess a life from two to four times as great as that of the best crude-retort carbons, and from four to seven times that of the various makes of manufactured amorphous carbons, such as those made from mixtures of a pitch bond and powdered petroleum coke or lampblack, etc. In consequence, the graphite electrodes are rapidly replacing all such forms in this line of work, and are even

proving more efficient and economical than platinum, on account of the excessive cost of the latter material. In electrolytic processes, however, where the anode is subjected to a more active oxidizing action, such as in the manufacture of chlorates, the deposition of metals from sulphate solutions, in the oxidation of chromic acid solutions, etc., the differences between the action of graphite and amorphous carbon, although still very much in favor of the former, are not so great, and both suffer considerable disintegration. In chlorate work platinum and platinum-iridium alloys are still extensively used as anodes.

In alkaline-cyanide solutions, in the recovery of gold and silver from its ores, iron anodes have generally been used, and in some cases platinum; but serious corrosion with the former, and the expense of the latter, have been decidedly disadvantageous. Here also the graphite electrode is proving successful. Although there is a slight coloring of the solutions with such electrodes, absolutely no corrosion is apparent, and with the proper current densities there is very little disintegration. The coloring of the solution prevents the use of graphite electrodes in electroplating with gold or silver in cyanide solutions, as here the deposited surface must be seen and examined during the operation, but in processes for the recovery of metals from their ores this element need not be taken into consideration.

The processes mentioned above represent the largest fields of electrolytic work in which graphite electrodes are now being used; but actual comparative tests which are being made in other and newer lines of work continually prove that the value and usefulness of this material to the electrochemical industry is still to be fully appreciated. All tests to which graphite has been subjected, however, have dealt purely with its chemical properties, or its ability to withstand, for a longer or shorter period, in comparison with other materials, the action of certain electrolytes. The results thus obtained do not in themselves give a true basis for comparison, for the ease with which graphite can be handled, its *adaptability*, purity, high electrical conductivity and other *physical* characteristics, should be given equal consideration. It is conceivable that these latter might in certain processes more than offset the single advantage of longer life possessed by some other form of electrode material.

Graphite electrodes can be machined with the greatest ease, and it is to touch upon this characteristic, and the consequent adaptability of graphite electrodes to almost any conditions, that this paper is written. Ease of machining, however, can be said to apply only to electrodes manufactured by the Acheson process. With this process all electrochemists are familiar, and a description of the method of graphitizing employed is unnecessary.

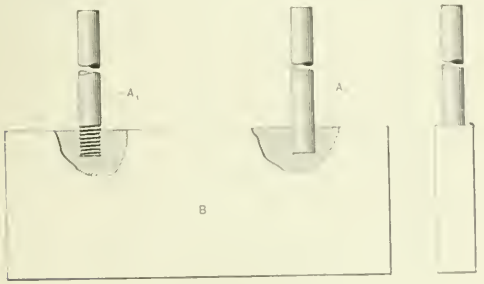



FIG. 1. GRAPHITE ELECTRODE.

In electrolytic work the size and shape of the electrode is determined more in reference to a certain surface area desired than to the cross section necessary to carry the total current used. For mechanical strength the electrode must be given a fair thickness, in proportion to its width, and with the low current densities of practical electrolytic work, the carrying capacity of its cross section is never approached. It is, therefore, of importance to design an electrode which will give a large surface area, with a minimum volume, and whose surface area will not decrease appreciably as slow, gradual disintegration takes place, assuring fairly uniform current densities. The ease of machining graphite electrodes, or their extreme adaptability, makes such forms possible.

In Fig. 1 is shown a form of anode consisting of a graphite slab *b*, into one edge of which are fitted graphite rods $a_1$, $a_2$, etc. These *leading-in* rods can be as many, or as few, as desired, and are designed to utilize the full electrical conductivity of graphite articles. They serve both as means of support for, and as the electrical conductors to, the slab *b*, or anode proper. The rods may either be threaded into the slab as $a_1$, or both the rod and the hole in the slab may be given a slight taper and a tight, drive fit made as in $a_2$. In Fig. 2 the slab is shown suspended vertically in the electrolyte.

FIG. 2. GRAPHITE ELECTRODE.

If a slab is used alone as anode, especially in cells which it is desired to keep tight for the collection of some liberated gas, as in chlorine work, connection must either be made by casting some form of metal head, unaffected by the gas in question, on the end of the slab, or, the slab must be brought through the cover of the cell and connection made with the metal conductors outside. In either case there is unnecessary electrode weight above the surface of the electrolyte, to be thrown away when the anode has been used. Furthermore, in the one case corrosion is apt to take place in the contact between the cast head and the slab, and in the other it is not always easy to make a perfectly tight seal around a slab of any size where it passes through the cover of the cell, and, consequently, some gases escape.

In the arrangement shown in Fig. 1, practically all of the main weight of the anode is active surface; the rods can be used over again; there is absolutely no deterioration of contact between the rods and slab, nor is there any difficulty in making a tight seal around the small rods where they pass through the cover of the cell. With the slow, gradual disintegration of the slab *b*, its surface remains fairly constant. To prevent any creeping of solution up through the rods or a possible escape of gases through the same, which might act on the metal conductors, the rods can be impregnated with paraffine.

If for any reason it is absolutely essential that connection with the metal conductors be made inside the cell, instead of casting a metal head to the end of the electrode, which must be re-cast every time the electrode is removed, a round graphite electrode can be used, which can be threaded on the end and screwed into a tapped hole made in the cast head. Electrodes can then simply be screwed into the same cast head as it becomes necessary to renew them.

The methods mentioned above have already proved very successful in actual electrolytic work upon a practical scale. Other forms even more complex are being used, which would have been wholly impossible with the old style of amorphous carbon electrodes. Although the style of anode shown is the simplest possible form, and is applicable to practically any process, special conditions might require other methods of machining and assembling. It is hoped, however, that with the above practical illustrations, other forms will suggest themselves which may be the most suited to the special work of the experimenter in question.

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

UNITED STATES PATENTS ISSUED JULY 1, 1902.

**No. 703,420.** Filed August 1, 1899; Rudolph M. Hunter, Philadelphia, Pa. Process of making accumulator plates.

The inventor casts a lead framework around segments of coiled or folded strips of lead, which he cools during the process with a stream of air, claiming to produce a "mechanically integral structure." To really accomplish this object would require not only the actual fusion of the segment of coiled lead at the points of union, but also either a flux or reducing agent to remove the film of lead oxide that is inevitably present. The wording of the specification indicates that the inventor does not intend to actually fuse the edges of the strips. It seems doubtful whether this method can compare favorably in cheapness with many of the well-known methods of making (by rolling or punching a plate), which consists of an integral structure of ribs and thin laminæ.

**No. 703,490.** Filed July 13, 1891; Malcon O. Smith, Depew, N. Y. Storage battery.

This battery consists of a cup-shaped cell of lead, the outside of which forms one pole and the inside the other pole. The form is adapted for the piling up of several cells in series and is very similar to that of G. Philippart, patented January 29, 1884 (No. 292,762).

**No. 703,541.** Filed January 22, 1891; C. C. Clark, Philadelphia, Pa. Water purifier.

An electrolytic tank inserted within a larger settling tank. Water is admitted through the electrolytic tank, where it is electrolyzed between perforated copper, platinum or iron electrodes; thence it passes into the settling tank. The settling tank is provided with tubes for cooling or heating, as the case may require, and with a dome for the collection and elimination of gases and lighter impurities. Details of construction.

**No. 703,623.** Filed June 26, 1891; Theodore F. Taylor, Camden, N. J. Electroplating apparatus.

Details of construction are claimed for a rotable drum, in which small articles are tumbled and plated simultaneously. There is a fixed anode and a cathode of revolving rings.

**No. 703,673 and 703,674.** Filed September 13, 1899; Elmer A. Sperry, Cleveland, Ohio. Assignee, National Battery Co. Electric battery and mounting same. Connection for batteries. Mechanical construction of battery jar or receptacle.

**No. 703,857.** Filed August 6, 1891; C. J. Tossizza, Paris, France. Electrometallurgical treatment of zinc ores and especially blend.

This patent is to provide a method for depositing zinc from solution by the joint action of electrolysis and a chemical reducing agent. The reagent employed is sulphurous acid. In order to prevent the reduction of sulphurous acid to sulphur or hydrogen sulphide, he makes two separate operations; one operation in which copper is dissolved and zinc deposited, the e. m. f. being 2.30 — 1.21 = 1.09 volts; the other operation in which copper is redeposited and $SO_2$ oxidized to $SO_3$. It is claimed that the two operations combined require only from 1.4 to 2 volts.

Such a double cycle has certain disadvantages. One which would be practically very great, is the introduction of copper into the electrolyte without contaminating the deposited zinc. The patentee does not state whether he prevents this by porous diaphragms or in any other way.

**No. 703,861.** Filed March 5, 1891; A. A. Vogelsang, Dresden, Germany. Electrolytic cell and electrode therefor.

"The object of the invention," as stated by the inventor, "is primarily to enable all-platinum electrodes to be used economically." Parallel electrodes of platinum foil, not connected to any source of current except the electrolyte, are so disposed in a trough that the electrode flows in a zigzag path over one and under the next from one end of the trough to the other. The terminal electrodes only are connected to a source of current. A portion, at least, of the current will evidently traverse the solution from end to end, entering and leaving only the terminal electrodes. Whether the total current will take this path or a part of it go through the suspended intermediate electrodes will depend on the electromotive force employed and the nature of the electrolyte.

**No. 703,875.** Filed March 14, 1901; Walter E. Winship, San Francisco, Cal. Active material for storage batteries and process of making same.

Lead oxides are mixed with water and glycerine into a paste, which sets quickly and firmly. This is reduced to spongy lead electrolytically in a bath of a fixed alkali carbonate. It is claimed that the slight solubility of the paste in the alkali carbonate causes the lead to "tree" in parallel crystals and form a mass of greater porosity and other desirable properties. It seems that some of the claims would cover broadly the well-known process of reducing lead chloride to metallic lead electrolytically, as for example, claim 1: "The process of forming an active material for storage batteries consisting in suitably binding a mass of lead salt which will retain its configuration after immersion, and reducing it by electrolysis to spongy lead in an electrolyte which is a solvent for the lead salt, and from which solution lead trees essentially parallel to each other are plated within the mass."

**No. 703,895.** Filed October 18, 1900; A. F. Clark, Philadelphia, Pa. Separator plate for secondary batteries.

The separator plate consists of hard rubber in the general form of a window blind with outwardly and upwardly projecting slats, forming pockets with the adjacent face of the positive plate, in which active material is retained and prevented from falling to the bottom of the cell.

UNITED STATES PATENTS ISSUED JULY 8, 1902.

**No. 704,010.** Filed May 23, 1898; Thomas A. Edison, Llewellyn Park, N. J. Apparatus for concentrating magnetic iron ores.

This is a combination of pulverizing rolls, screens, drums, magnetic separators and conveyors.

**No. 704,125.** Filed July 20, 1891; W. T. Seddon, Minersville, Pa. Battery.

Mechanical details of structure of a battery consisting of zinc and carbon electrodes, the carbon electrodes being hollow and containing "chrome salt solution." No electrolyte is mentioned except the "chrome-salt solution."

**No. 704,252.** Filed July 30, 1901; Henry K. Hess, Philadelphia, Pa. Process of making plates for storage batteries and product thereof.

Active material is molded into the form of a plate and at the same time molded around the conducting metal strips by means of pressure. Details of the mold are described.

**No. 704,303.** Filed January 8, 1901; Thomas A. Edison, Llewellyn Park, N. J. Reversible galvanic battery.

This battery comprises an oxide of mercury anode and a cathode of zinc, deposited upon metallic magnesium, the electrolyte being an alkaline solution. The oxide of mercury is mixed with flake graphite and confined in a perforated nickel receptacle. The general construction of this receptacle has been described by the inventor in previous patents, particularly in an application filed October 31, 1900. The advantage claimed for oxide of mercury is that no particles of the oxide, when reduced and in contact with the zinc, produce local action.

They merely amalgamate the zinc instead of producing local action. In this connection the inventor says: "with almost every other oxygen-storing element of which I have knowledge, infinitesimal amounts thereof are dissolved in the alkaline solution and produce objectionable local action on the zinc."

The use of metallic magnesium, on which zinc is deposited, as an accumulator plate, is singular, as it would seem that the highly electropositive properties of magnesium render it extremely liable to oxidation. This is particularly true when it is amalgamated; an amalgamated strip of magnesium in contact with pure water is rapidly converted into magnesium hydrate with the evolution of hydrogen gas. The use of oxide of mercury as a positive element instead of lead peroxide, requires about the same weight of material for a given capacity in ampere hours.

**No. 704,304.** Filed March 1, 1901; Thomas A. Edison, Llewellyn Park, N. J. Reversible galvanic battery.

The object of this patent is to claim specifically oxide of cobalt ($Co_2O_3$) as a depolarizer in an alkaline reversible galvanic battery. The oxide of cobalt is mixed with graphite or other flake-like conducting substances. Oxide hydrate or dioxide of cobalt is prepared in the usual way by precipitation. After drying, powdering and pulverizing very finely, it is mixed with one-seventh of its weight of graphite. Finely divided iron is mentioned as the negative plate.

**No. 704,305.** Filed May 17, 1901; Thomas A. Edison, Llewellyn Park, N. J. Electrode for storage batteries.

Claims a receptacle for active material for a storage battery, comprising a pocket of perforated and corrugated metal with a support for the same. It is found necessary in a battery of the iron-nickel-alkaline type to retain the active material in close contact by means of pressure with the conducting support. Perforated metallic cases or pockets of very thin sheet steel, plated with nickel, have not sufficient rigidity to maintain an intimate contact by pressure under the influence of expansion and contraction due to charging and discharging. By corrugating the perforated metal, however, the rigidity of the receptacle is greatly increased, as well as the amount of expansion it will undergo without exceeding the limit of elasticity.

**No. 704,306.** Filed July 20, 1901; Thomas A. Edison, Llewellyn Park, N. J. Reversible galvanic battery.

The claims cover specifically the combination of finely-divided copper negative plate and nickel or cobalt oxide mixed with flake graphite as a positive plate in an alkaline solution. The construction is substantially the same as the Edison nickel-iron battery with the substitution of finely-divided copper for the iron. It is stated that oxide of cobalt is not as desirable for this use as oxide of nickel, "owing to the greater cost and to the fact that it is slightly soluble in the alkaline electrolyte." Both active materials are intimately mixed with an inert flake-like conducting substance, such as flake graphite, to increase the conductivity of the cell. Pure carbonate of copper is reduced by hydrogen at the lowest possible temperature, not exceeding 500° Fahrenheit for six or seven hours, until the copper is converted into its black oxide. The inventor states that unless the copper is in a very finely-divided form throughout, a soluble blue salt is produced, which results in local action and rapid deterioration of the elements. The nickel hydrate is prepared in a non-colloidal form by adding to a boiling solution of nitrate of nickel a sufficient quantity of magnesium hydroxide to precipitate the nickel as hydroxide.

**No. 704,349.** Filed March 15, 1901; Eugene Lecomte, Estaires, and Jerome Loiselet, Paris, France. Process of manufacturing rice starch or other amylaceous substances.

The rice or other grain, after washing and soaking in a dilute alkaline solution, and after being finally washed with pure water, is ground into a paste, diluted and rendered alkaline by sodium carbonate to the extent of one gram of soda per liter. The object of the sodium carbonate is to produce electric conductivity and to assist in removing the gluten. The solution is then electrolyzed in tanks with "electrodes of aluminum, zinc or any other suitable matter." The action of the current precipitates gluten and other organic matters, leaving the starch practically pure.

**No. 704,393.** Filed February 27, 1901; Albert Simon, Bordeaux, France. Manufacture of iron, manganese and alloys of these metals by aid of electricity.

The material is dissolved in fused calcium fluoride in an electric furnace of special construction. The iron, manganese or alloy is deposited electrolytically on the cathode by a continuous current. The inventor states that the "silicon reduced under the action of the current combines with the free fluorine to form the gaseous fluoride, which is set free, so that the metal only retains but small quantities of silicon." How the fluorine set free at the anode combines with the silicon liberated at the cathode, thus chemically removing the reduced silicon from the reduced iron or manganese, is not explained by the inventor.

**No. 704,399.** Filed December 16, 1895; Julius Taluau, Philadelphia, Pa. Stained glass window or similar object, and process of making same.

**No. 704,400.** Filed June 30, 1897; Julius Taluau, Philadelphia, Pa. Method of framing glass.

**No. 704,401.** Filed March 22, 1898; Julius Taluau, Philadelphia, Pa. Method of framing glass.

These three patents all relate to improved methods of uniting small pieces of glass into an ornamental framed plate. Plates of this kind have heretofore been made by running strips of lead between the adjacent pieces of glass and soldering at the joints. By the electrolytic process the pieces of glass are laid upon a conductor, such as a sheet of lead with spaces between for the electrodeposition of copper. The pieces of glass may be fixed in place by means of wax. The plate is then placed in a bath of copper sulphate as a cathode, the deposited copper filling the spaces between the pieces of glass and uniting the whole into a rigid substantial frame. By this process the most intricate designs composed of very small pieces may be united at very little expense.

### UNITED STATES PATENTS ISSUED JULY 15, 1902.

**No. 704,639.** Filed September 27, 1899; Carl Hoepfner, Frankfort-on-the-Main, Germany; Henry Orth, Jr., administrator. Leaching and extraction of metals from their ores.

The improvement covered by this patent over previous processes of Hoepfner for extracting copper from sulphide and other ores, consists in the use of a solution of cupric chloride in a non-saturated solution of sodium chloride. Instead of the quantity of chloride of sodium which would saturate the solution the inventor uses from one-quarter to three-quarters of that quantity. He finds that cupric chloride solutions containing less than the saturating quantity of chloride of alkali or alkaline earth metals can be made more concentrated in cupric chloride. When heated to from 60° to 100° C. these solutions are very active solvents of copper, copper sulphide, silver and other associated metals with formation of cuprous chloride, also of cuprous chloride, lead chloride or silver chloride, which are rendered partially insoluble by cooling, thus offering a very easy means of separating these salts.

**No. 704,640.** Filed June 25, 1895, and October 30, 1901; Hudson Maxim, Brooklyn, N. Y. Electrical furnace for treating highly refractory substances.

A special form of rotating horizontal tubular electrical furnace, having a screw feed for forcing the material to be operated upon into the furnace at one end and out at the opposite end. A peculiar feature of this furnace is a fused lining of material, having greater specific gravity than that of the material treated. This fluid lining is maintained by cen-

trifugal force in its position in the form of a liquid tube surrounding the material to be operated upon. The furnace is intended particularly for the production of calcium carbide.

**No. 704,675.** Filed July 27, 1901; David H. Browne, Cleveland, Ohio, and Thomas M. Niel, Toronto, Can. Process of recovering metallic tin.

Scrap tin and ores of tin are treated with a solution of ferric chloride, heated and slightly acidulated. The tin is dissolved and the ferric chloride reduced to ferrous chloride. The second step in the process is the deposition of the tin electrolytically from the solution at the cathode and the reoxidizing of the ferrous chloride to ferric chloride at the anode. A porous diaphragm is used to separate the analyte from the catholyte. The solution is first used as a catholyte, from which the tin is deposited, leaving iron as ferrous chloride. This solution then becomes the anolyte and is reoxidized to ferric chloride.

**No. 704,739.** Filed October 3, 1900; J. B. Entz, Philadelphia, Pa. Secondary battery.

The object is to produce a lighter accumulator for automobiles. A special form of corrugated grid of antimonial lead provided with projections or perforations for holding the active material is employed. The plate is constructed of rolled antimonious lead, which, it is claimed, becomes malleable by reason of the rolling. Eight per cent. of antimony is recommended. This material does not oxidize under the action of the battery and is, therefore, durable, "retaining its initial strength during the existence of the plate."

**No. 704,744.** Filed April 28, 1902; Herman Heinicke, Schoeneberg, near Berlin, Germany. Electric accumulator.

A special form of grid or support for the active material, consisting of a conducting base with angular grooves extending from top to bottom and horizontal strips which assist in retaining the active material.

**No. 704,751.** Filed July 30, 1901; Harold M. Martin, Philadelphia, Pa. Manufacture of secondary-battery plates of the Planté type.

This patent claims broadly the process of rapidly forming a storage-battery plate by electrochemical means and controlling the temperature, particularly by keeping the temperature of the electrolyte below 115 Fahrenheit. This is done "by abstracting heat from it" when its temperature increases. There are many processes in common use for forming active material electrochemically which generate heat and cause an increase of temperature. The abstraction of heat seems to be the only possible way of keeping the temperature down and is the method always used. The novelty of such a process as cooling an electrolyte by abstracting heat from it is not apparent.

**No. 70,4759.** Filed July 29, 1901; Hugh Rodman, Philadelphia, Pa. Storage-battery separator.

The combination of storage-battery plates with an imperforate wooden diaphragm between each pair of plates, said diaphragm having acid wells both sides thereof in a substantially vertical position. The object of this separator is to provide a free circulation of the acid from the top to the bottom through vertical grooves or wells cut on the sides of a wooden sheet. These grooves may be parallel on both sides or those on one side may cross grooves on the opposite sides at a small angle. The latter arrangement would probably give greater stiffness and durability. Any kind of wood may be used, but porous or fibrous wood is particularly recommended. It is stated that diaphragms of wood possess unique and remarkable properties which adapt it for the purposes. The remarkable properties mentioned are efficiency, durability and capacity.

**No. 704,767.** Filed September 20, 1900; Edward G. Steinmetz, Philadelphia, Pa. Secondary battery.

The object of this invention is to avoid the casting of lead chloride and its detrimental effect upon the health of the workmen, also to avoid the production of blow holes. A crystalline structure is imparted by subjecting the mass of lead oxide or lead salts to electrolytic action in a bath capable of dissolving it, the salt or oxide going into the solution and immediately re-depositing it in a metallic state of crystalline structure, without any substantial change of external form of the mass. The material is first molded or stamped into blocks or cakes. A lead grid is cast around these cakes in the usual manner. The plate is then used as a cathode in an electrolyte, in which the lead salt or compound is insoluble. The improvement consists in stamping or molding the material instead of casting it into cakes or blocks. In all other respects the process and results are identical with others in use; such, for example, as the well-known "chloride" battery plate, the cast-lead chloride being soluble, as well as the molded.

**No. 704,831.** Filed June 1, 1901; Charles B. Jacobs, East Orange, N. J. Process of manufacturing sulphuric acid from sulphur dioxide in aqueous solutions by electrolysis.

Claims the process of making sulphuric acid by passing sulphur dioxide through a porous anode and setting free the oxygen of water upon said anode. A horizontal porous conducting plate, cemented into a jar, forms a partition dividing the upper part of the jar from the lower. Sulphur dioxide is admitted below this partition and is caused to pass through the pores into the upper chamber containing sulphuric acid. The temperature is maintained by refrigeration at zero centigrade, in order to secure a concentrated solution of sulphur dioxide. Strong acid is produced and is drawn off when it reaches the proper strength, as indicated by a hydrometer. A pressure of 2 volts and a current density of 15 to 20 ampères per square foot anode surface is used. The inventor states that 500 ampères will produce one ton of 50° Baumé sulphuric acid in three hundred and three hours, with a theoretical efficiency of 54 per cent. There seems to be some mistake here, as this quantity of electricity would produce only 203 kilograms or 450 pounds of concentrated sulphuric acid, while one ton of 50° Baumé acid would contain 1,240 pounds of the concentrated acid. Pure $SO_2$ is obtained by saturating water with the gas at the freezing point, under which condition $H_2SO_3$, $14H_2O$ are separated, leaving the impurities of the gas behind.

**No. 704,850.** Filed November 21, 1901; Victor Cheval and Joseph Lindeman, Brussels, Belgium. Electric accumulator-electrode.

A form of construction in which the negative plate consists of a single mass, having vertical cylindrical or prismatical holes, into which a number of positive electrodes in the form of rods are inserted.

**No. 704,903.** Filed January 8, 1900, and May 16, 1902; Frederick C. Weber, Chicago, Ill. Electric smelting furnace.

A vertical tubular furnace, having numerous electrodes in the form of rods arranged radially and adapted to produce ares within the tubular furnace chamber of varying intensity at different points and subject to regulation.

### United States Patents Issued July 22, 1902.

**No. 705,076.** Filed February 19, 1902; Charles M. Hall, Niagara Falls, N. Y. Manufacture of carbon electrodes.

A furnace for baking carbon electrodes, particularly such as are to be used for the electrolysis of fused baths. The carbons are placed in proximity to an electrically-heated carbon core and insulated therefrom, the object being to prevent as much as possible of the current from passing through the carbons themselves and to develop the heat in the carbons gradually by radiation. It is claimed that carbons thus produced are of greatly improved quality.

[*Lack of space requires that several patents issued in July be reserved for the next issue.*]

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

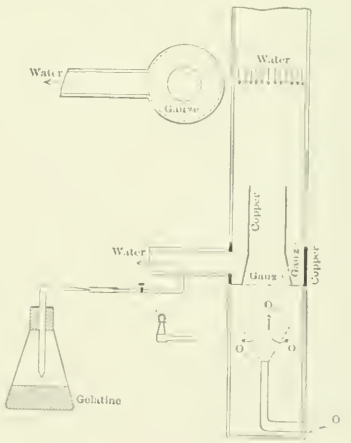
*A Summary of all Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

BY CARL HERING.

## INDUSTRIAL ELECTROCHEMISTRY.

*Metal Refining.*—A good process may readily be a commercial failure if it is not properly carried out from the industrial standpoint, while, on the other hand, a poor process may sometimes, by good design of the installation and good management, be made a commercial success. As so much depends on the proper design and arrangement of such installations, an article by PHILIP, begun in the Lond. *Elec.*, August 1st, and containing many statistics and formulas, will, no doubt, be of interest to those who have the responsibility of designing plants for electrolytic metal refining, as he has for many years past collected and tabulated all the available details of such installations, in order to elaborate a connected scheme by means of which the task of designing an electrolytic refinery upon a sound financial basis might be successfully undertaken. The general method which he adopted was to endeavor to arrive at a formula for every item of outlay, expressing it in terms of all the variables involved, and then to insert in this a constant or constants obtained by calculation from all the available and trustworthy figures hitherto published with regard to the particular item of outlay under consideration. For instance, the power employed in an electrolytic copper refinery must vary directly with the number of tons output per year, when the current density is kept constant; while, on the other hand, if the output is kept constant, then if the current density is doubled (neglecting the back e. m. f. at the electrodes, which is small and constant) the voltage must also be doubled, while only half the total number of vats will be used; hence the power required must be doubled. He thus arrives at a formula stating that the cost of the power plant must be proportional to the product of the annual output of refined copper and the current density. This, of course, applies only to such cases in which the counter e. m. f. may be neglected. He then takes up in detail the problems of the establishment of an electrolytic copper refinery. The first point is the amount of capital available, the other important points are current density, area of ground, tons of copper to be refined per year and profit available per year; the current density is always the ruling factor. Taking up first the capital expenditure, the cost of offices in pounds sterling is given as 150 + 1-10 the number of tons refined per year. The area of refinery buildings for a given yearly output is inversely proportional to the current density; the area in square feet is given as 30 times the ratio of the number of tons refined per year to the current density in ampères per square foot; the constant 30 is an average value, in six different plants it varied between 21.9 and 31.5. The cost of the buildings in pounds sterling is given as 7.5 times the ratio of the output in tons per year to the current density in ampères per square foot. The power required varies directly as the output per year and also directly as the current density employed. If gas engines with gas producer plant are installed, and if the prime cost of supply and erection of this plant is $80 per horse-power installed, then the prime cost of the plant in pounds sterling, including the erection of gas engine and producer plant, may be fairly given as 0.12 times the product of the output in tons per year and the current density in ampères per square foot.

*Sterilizing Water by Ozone.*—That ozone is a powerful destroyer of organic matter, be it vegetable or animal, is as well known as the fact that most drinking waters need sterilization. The question, therefore, is not whether water can be sterilized with ozone, but it is to show that it can really be carried out effectively at a cost which is not prohibitive; it is, therefore, a question which can be decided only in actual practice on a large scale. If ozone could be generated at anything approaching the theoretical efficiency, the problem would probably be a comparatively easy one, but even the best ozone generators are horribly inefficient, as they generate only a few per cent. of the amount of ozone which corresponds to the energy consumed. There are other practical difficulties, such as getting the gaseous ozone in contact with each of the particles of such enormous quantities of water as are used in a city. Many systems have been proposed and some have been tried, but few have survived. The Vosmaer-Lebret system, however, seems to have stood a fair trial, as it has been used commercially in Schiedam and later in Nieuwersluis, near Amsterdam. In the former city it was used for eleven hours per day during two periods of six months, without any interruption, which speaks well for it. A description of this process was recently given in a Bunsen Society paper by H. J. VAN'T HOFF, which is reprinted in the *Zeit. f. Elektrochemie*,




July 24th. Briefly described, there is an alternator generating current at 110 volts and 100 periods, which is raised to 10,000 volts by transformers, and is used directly at this voltage to generate ozone. The apparatus itself consists of a large number of metal tubes, in each of which the ozone is formed by means of the so-called dark discharge, there being a special device (not described) which prevents any other and undesirable forms of discharge, such as sparks or arcs, and it thus becomes possible to work without any solid dielectric, which is a great advantage in practice, as glass would be the only dielectric to use, and this is apt to break. The air is first dried by means of chloride of calcium, and is then passed through the apparatus at the rate of 40 liters per minute or even faster. No cooling is resorted to and a concentration of 3.5 to 5 milligrams per liter is obtained, depending upon the speed of the air; from 3 to 3.5 has been found sufficient for sterilization purposes. This ozonized air is then pumped into the sterilizer, entering at the bottom and leaving at the top, as shown in the adjoining illustration, the coarse impurities in

the water having first been filtered off by means of a rapid filter. The article gives some details of tests which were made. The results are said to be at least as good as with other ozonizing systems, the figures for which are given in a small comparative table. The cost is said to be 1-16 to $\frac{1}{8}$ cent per cubic meter, by which he presumably means that much water and not that much ozonized air; this, though it may be a low price for ozonizing, is, nevertheless, rather a high price for sterilizing water. The cost of the installation, which presumably is not included in this, is not given, as it is said to depend on local conditions. The author of the paper fully agrees with the statement recently made by Ohlmueller and Prell, of the Imperial Board of Health, that a considerable destruction of micro-organisms is accomplished by ozonizing, and that in this respect it is generally superior to sand filtration. It is proposed to introduce ozonization at the water works in Rotterdam and, if this is done, the results will be awaited with great interest, although the prospects of reducing the expense, which seems to be the great drawback, does not seem to be very promising.

*Calcium Carbide.*—Now that the production of calcium carbide has grown to such enormous proportions, a discussion of the detailed reactions which occur during its formation become of interest. An article in the *Zeit. f. Electrochemie*, July 19th, by Gin, whose name is so well known in connection with this industry, describes these reactions in some detail. Strange as it may at first seem, it is known that the gases formed in different parts of the furnaces contain both free oxygen and free calcium; the former increases with the current density and is formed where the temperature is highest, while the calcium vapors issue from the places where the temperature is lower. The oxygen burns the electrodes immediately below the surface of the molten mass. The calcium is deposited in the form of a fine dust, which consists almost entirely of this material. To explain the formation of the latter he recalls some experiments of Berthelot, which showed that carbonous oxide is dissociated at high temperatures; there is also a surplus of calcium oxide in the charging mixture used, which is not always mixed according to the formula of Bullier. Moreover, there is always a series of layers in the mass in the furnace, the temperatures of which decrease towards the outside and in which, therefore, there are different chemical reactions, of which the more endothermic are at the higher temperatures. When the temperature is high enough to dissociate carbonous oxide entirely, the formation of calcium carbide consists of a simple substitution of oxygen by carbon in the calcium oxide, oxygen being set free, while calcium vapors are developed at the surfaces where the calcium oxide and the calcium carbide meet.—The present conditions of the calcium carbide and acetylene industries are summarized in an article by Muensterberg in *Rev. Gen. des Sc.*, June 15th. He goes so far as to say that the light of the future in small cities and in isolated buildings will be generated by acetylene, a statement which has been made before, but has not yet come true. Nevertheless, it is known that vast quantities of calcium carbide are now being made, and as they do not seem to be consumed in the large cities, they must go largely to the smaller ones.

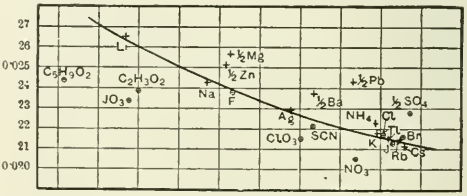
*Gold.*—Now that the unfortunate war in the Transvaal is at last over, attention is again diverted to the enormous gold-mining industry in that country. The general conditions of gold mining in the Transvaal, where the Siemens & Halske process is used largely, is discussed in an illustrated article in *Cassier's Mag.*, for July, by Hammond. While the percentage of extraction is said to be the same as in the zinc-precipitation process, the cost of the electrolytic process is said to be slightly greater, but the process may be supplied to any solution, whether weak or strong. As is well known, lead cathodes are used there, which are afterwards melted and cupelled, yielding a bullion of 0.880 in gold and 0.1 in silver; they are said to be removed once a month, which seems rather a long time as the daily interest on the value of the gold in such processes is often quite great. There is an installation, for instance, which the present writer has had occasion to examine, in which the stoppage of the plant for a single day involved a loss of interest amounting to several thousand dollars; this, however, was a refining process in which, of course, the amount of gold handled per day was far greater. It would seem that there was room for improvement in the use of a different kind of cathode, from which the gold could be stripped more frequently without involving the process of cupellation. The voltage used in this Siemens & Halske process is between 2 and 3, and the current density about 0.06 ampère per square foot of cathode.

*Tin from Scrap.*—The recovery of the tin from the waste scrap of tinned iron has occupied the attention of many inventors, but notwithstanding this, vast amounts of this material are being thrown away or merely melted for a low grade of iron, in which strength and purity are no object. A noted English writer once said that the greatest difficulty in the electrolytic process was not to get the tin from the iron, but to get the scrap itself. Although this may be the case, yet we believe that if a good commercial process is found the scrap will also be found, as is already the case in Germany. A process which seems to solve the difficulties was recently described in a very long article by Menicke in the *Zeit. f. Elektrochemie*, May 22d, June 5th and 12th. The scrap is used as an anode in a sodium hydrate solution, from which the pure tin is deposited on the cathode, while the iron and other impurities remain in the sludge under the anode. The formulas of the reactions are given, and he discusses at great length the practical questions involved. This process is in use on a very large scale in many large German cities, especially in Essen, and is claimed to be very remunerative, and to be one of the important electrochemical industries in that country. The price of tin is so high that it would seem that such processes could also be introduced to advantage in this country.

*Furnaces.*—A new form of resistance furnace for laboratory purposes, in which a spiral of platinum foil is used, is described in an article by Heraeus, abstracted in the Lond. *Elec.*, July 18th. Some formulas for determining approximately the temperature and efficiency of electric resistance furnaces is given in an article by Gin in the *Electrochem. Zeit.* for May.

## THEORETICAL AND EXPERIMENTAL.

*Electrochemical Theories.*—The modern dissociation theory, although a very valuable one and a very creditable one to its authors, has been so seriously attacked that it should still be, strictly speaking, called a hypothesis or, at least, limited to a narrower scope than its originators claimed for it. But as all such hypothesis when they have stood the test of trial sufficiently well to be applicable in practice are of great inter-




Mobility of ions and temperature coefficient.

est and value, articles on these theories, especially by such distinguished pioneers as Dr. Kohlrausch, the well-known president of the Reichsanstalt, and Dr. Hittorf, will always be read with interest. In one by the former, published in the *Sitzungsbr. Berl. Akad.*, May 29th, and abstracted in the Lond. *Elec.*, August 1st, he describes an interesting investigation, in which he succeeded in discovering and confirming a new law concerning the mobility and temperature coefficient of the

conductivity of monovalent ions. He seems to have found the interesting fact that the temperature coefficient is simply a function of the mobility, whatever be the chemical nature of the ion. Referring to the adjoining figure, the mobilities at 18° are shown as abscissas and the corresponding temperature coefficients as ordinates, and it will be seen from this that the monovalent ions Li, Na, F, Ag, K, Cl, Tl, I, Br, Rb, Cs, are all on the same curve, while ions of other valencies are not. Moreover, he found that the mobilities of the positive and the negative ions tend to become equal at rising temperatures. In attempting to frame a theory of this curious disappearance of the intrinsic differences of the ions, he conceives the ions as being surrounded with a film of water, whose thickness varies with the nature of the ion and reduces the mobility to a function of the friction of water against water, thus forming a third element which governs the two quantities, which he has shown to be dependent on each other. In the other paper above referred to, by HITTORF, the author shows his true scientific spirit by calling attention to, and correcting, a mistake in his determinations of transport numbers which he made about forty-five years ago. When clay diaphragms are used, there is no change of composition of the solution as it passes through the diaphragm, and in such cases there is no error in the transport numbers due to the diaphragm through which endosmosis always takes place; but when such diaphragms are made of animal membranes the action is different, at least for most aqueous solutions, as changes occur in the anode and cathode compartments which are not due to the electrolytic transference of the ions, even when the concentration is the same at the start, and, therefore, a determination of the transport numbers from the observed concentration changes may give wrong results. This is described in a Bunsen Society paper, in the discussion of which Le Blanc suggested that a diaphragm might be considered as a new kind of a solvent, in which the mobilities of the ions are different from what they would be in pure water, but the author did not seem to accept this hypothesis. The paper is reprinted in the *Zeit. f. Elektrochemie*, July 24th.

There is another paper on the theory of electrolysis, which was begun in the *Elek. Zeit.*, June, by PLATNER. It is a mathematical article on the electromagnetic theory of Maxwell and its application to the phenomena in electrolysis.

*Faraday's Law.*—It is a fortunate thing for electrochemists that Faraday's law, like Ohm's law, has so far withstood all attempts to show that it is incorrect, but, again like with Ohm's law, its application should be limited, or, in other words, it should be applied only to cases in which no other elements enter which are not really included in the law itself. Ohm's law, for instance, does not apply directly when counter e. m. f's. or reactances exist in the circuit; there are similar cases in the application of Faraday's law. In a recent paper by BOSE, abstracted in the Lond. *Elec.*, June 13th, he discusses the range of validity of Faraday's law, calling attention to disturbing factors. For instance, the cation may be capable of existing with two different valencies, and in such cases it might be claimed that the law does not apply; such a case, for instance, is the one in which one bivalent ion reacts with one atom giving two monovalent ions. In another case, to which he calls attention, the apparent discrepancy is due to secondary reactions, as, for instance in the deviations found in the electrolysis of silver salts, such as in the silver voltameter, which amount to 0.0001 of the total weight of the silver deposited; among the important secondary reactions is the occlusion of oxygen by the platinum electrode. It might be said that such cases are somewhat analogous to an unknown leakage in an electric circuit, in which Ohm's law could no longer be applied directly; such errors, however, are due to an incorrect application of the law and not to an incorrectness of the law itself. He regards Faraday's law as an absolutely exact law of nature, and believes that there is absolutely no evidence of any metallic conduction in electrolytes, the whole current being conducted by the transportation of materials. He compares Faraday's law with Dalton's law of multiple proportions, as far as exactness is concerned, and considers it an extension of Dalton's atomic laws.

*Heat of Combination.*—The probable source or origin of the heat of chemical combination is a fruitful source of speculation, and while probably of no great importance is, however, of considerable interest. T. W. RICHARDS, in a recent paper, calls attention to the fact that in many cases the contractions which are found to take place during different chemical combinations, are approximately proportional to the heat evolved, and he, therefore, believes that the whole source of chemical combination is the work performed in compressing the material; he carries this still further back and attempts to explain the origin of the heat of absorption, change of allotropic form and adhesion, which leads him to a hypothesis of the compressibility of atoms, which is discussed in detail. The paper is to be found in the *Proc. Am. Acad.*, Vol. 37, page 399, or in the *Zeit. Phys. Chem.*, Vol. 40, page 897, and is abstracted briefly in the *Am. Jour. Sc.* for July.

*Atomic Weights.*—While the question of atomic weights is a purely chemical one, yet the actual values are of such importance to electrochemists that laws concerning their relations are of interest here. Numerous papers have been written showing curious relations between atomic weights, intending to lead to some law existing between them, but most, if not all, of these fail to apply to some of the other elements. VINCENT, in a recent paper in the *Phil. Mag.*, for July, abstracted in the Lond. *Elec.*, July 11th, brings out a new numerical relation of this kind. He shows that the atomic weights are a certain power, namely, the 1.21 of a specific number for each element, which numbers are an ascending series and are always whole numbers, hydrogen being, of course, 1. This series shows certain gaps which he believes belong to elements which are yet to be discovered. A question, of course, is which serial number should be assigned to the element; iodine, for instance, shows the largest error, as the atomic weight thus calculated is incorrect by about 3.9 units, and to make this error fit his theory, he suggests that perhaps the wrong serial number was given to it; as these are all whole numbers, however, it would seem that there ought to be no difficulty in either finding the proper serial number, if the theory is correct, or if this cannot be found, then so much the worse for the theory. By changing its place with telurium, the results would correspond better with his law.

*Gaseous Electrolytes.*—Gases are found to have a property of being able to dissolve and ionize salts according to experiments made by HAGENBACH, described in the *Ann. d. Phys.*, No. 7, an abstract of which appears in the Lond. *Elec.*, July 4th. In his experiments he made a cell with platinum and copper electrodes, the solution being rubidium iodide in liquid sulphurous anhydride; rubidium iodide was chosen because it dissolved easily and had good conductivity. The resistance of the cell at 157° C., which is above the critical temperature, was 500,000 ohms, but the e. m. f. was not sensibly affected by this rise of temperature; it was 0.12 volt at 100° and 0.07 at 20°, while at the above-mentioned temperature it was 0.1. Iodide of copper was formed by the oxidation of the copper electrodes. He explains the low conductivity of gaseous electrodes by stating that while the gas is capable of ionizing a salt in solution, yet there are so many more chances for the re-combination in a gas than in a liquid that the number of free ions is kept very small.

*Sulphur.*—Among the other experimental researches described during the past month, is an article of some interest by RIEDER, published in the *Zeit. f. Elektrochemie*, June 5th. He found that a compound of copper and sulphur was formed electrolytically, or, at least, during an electrolytic process, under certain conditions. The cathode in the copper plating bath was made in the form of a bar surrounded by a non conducting cylinder of sulphur, but the bar was also exposed to the elec-

trolyte above this ring of sulphur, and after about twenty hours the sulphur cylinder had become blue black over its surface where it was in contact with the copper, while the latter had been eaten away somewhat at the same point. He believes that this compound acts like an electrolyte and that its formation continues deeper into the sulphur; if the latter is made conducting by the admixture of a powdered conductor, this compound forms all over the surface at once. He also tried using this compound as one plate of a battery, the other of which was zinc and the electrolyte ammonium chloride mixed with zinc chloride; when giving current, hydrosulphurous acid is formed, which in turn forms zinc sulphide; he does not, however, make any great claims for this combination as a useful battery. Another experimental research in which sulphur plays a part, was described by Kuester in a Bunsen Society paper, abstracted in the same journal July 24th. In electrolyzing polysulphide solutions, he noticed that the measuring instruments showed periodic variations, and upon investigation he found that they were due to a layer of sulphur on the anode, which was periodically formed and destroyed, acting like an insulator while it was there. He is still seeking for an explanation of the cause, but gives some preliminary results for the potential difference between platinum and silver electrodes and different concentrations of different chlorides saturated with sulphur.

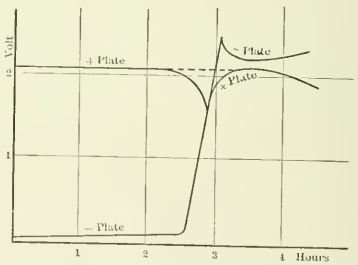
*Bromine.*—Kellner, several years ago, found that pure, dry chlorine gas had properties which ordinary chlorine has not, when high-tension currents are sent through it. In a recent Bunsen Society paper, published in the *Zeit. f. Elektrochemie*, July 24th, he describes experiments made with carefully-purified bromine in vessels of glass free from lead, and found that after some days yellow crystals had been deposited on the walls of the vessel, which he is sure do not come from the glass, but he does not know what they are. Some of those who discussed the paper concluded that it was a compound of bromine with the glass, while Ostwald suggested that it might be a case of isomerism.

*Alternating Current Electrolysis.*—This subject has been the basis of much research but as yet without much practical value, though nevertheless of interest. One of the ruling factors seems to be the current density, and we presume that the frequency of the alternations also has a considerable effect on the result, for it is not unreasonable to suppose that when the electrolytic process is not reversible a compound will be formed if the current continues in one direction long enough to overcome what polarization there may have been, and if the process is not reversible this compound will not change on the reversal of the current. Trotter recently made some experiments with alternating currents between lead plates, from which he concludes that such currents will electrolyze lead pipes if the current densities are lower than 1 ampère per square inch, which is an extremely high-current density, but the amount of the electrolysis, he claims, should be determined by those who advocate electric traction by alternating currents as a solution of the problem of destruction by return earth currents; but unfortunately those are the very ones who would prefer to assume that the amount was zero. The experiments are described in the Lond. *Elec.*, July 11th. He used lead pipes a few inches apart, separated by moist earth; the frequency was 83, the voltage 100 and the dampness was adjusted to maintain 1 ampère, which does not convey any idea as to the actual amount of dampness. He thus found that after six weeks there was a well-defined incrustation on the lead, confined to certain parts of the pipe. He repeated these experiments for other current densities. The nature of the earth used is also somewhat indefinitely described, as he stated he took it from his garden in front of the office.

*Chlorides.*—Mueller, in the *Zeit. f. Elektrochemie*, July 3d, gives an illustrated account of experiments in which he investigated the electromotive behavior of hypochlorus acid and chloric acid, in which he found a great difference when he used plain platinum anodes and when he platinized them, obtaining much better results in the latter case.

## PRIMARY AND SECONDARY BATTERIES.

*Lead Batteries.*—Several articles have been published recently on the lead accumulator, some of which are of interest as showing that although this is a well-threshed-out subject, there are still matters of interest cropping out. Frequently the plates of an accumulator are simply connected together regardless of their individual capacities, and then as a rule the useful capacity of the whole accumulator depends largely upon the weakest plates, especially with high discharges. It is therefore of interest to be able to determine the behavior of individual plates, or groups of plates, during a discharge, as in a well-constructed accumulator, where lightness is an important consideration, it is very desirable to have all the plates of exactly the same capacity and the end plates of half the capacity of the others. This may be done by means of an auxiliary electrode which serves to measure the potential difference between that electrode which is assumed to be standard and the plate to be tested. A method known as Fuch's method was recently applied by Liebenow, whose name is well known in connection with accumulator researches, and is described by him in a recent Bunsen Society paper which has not yet been published in full, but is abstracted in the *Elek. Zeit.*, June 12th. He applied it to a battery with two




DISCHARGE CURVES.

plates, or sets of plates, and claims that the method is very useful in repairing batteries that have lost their capacity. He describes three different forms of auxiliary electrode. The first consists of a cadmium plate in an ebonite frame, and is sufficiently good for rough determinations; care should, however, be taken that when the plate has been used the sulphuric acid should not be left to dry on it, as cadmium sulphate would be formed, which would cause errors in the next test. Zinc instead of cadmium is not suitable because zinc dissolves much more rapidly in sulphuric acid than cadmium. For more exact measurements Liebenow uses solid cadmium amalgam, which is suspended in a small bottle of "Pukall" material (a material much used in Europe for porous diaphragms) and is surrounded by a solution of cadmium sulphate and sulphuric acid; such an electrode is very constant. It is placed over the plates in the accumulator. During the discharge of the e. m. f. between this auxiliary electrode and the two battery electrodes is measured and the curves are plotted with the e. m. f's as ordinates and the times as abscissas. A sharp bend in a curve shows that the capacity of the plate is exhausted. For very exact measurements a small, carefully-treated accumulator plate is suitable; as an auxiliary for testing the negative plate a small, spongy, lead plate is used, and for testing the positive plate a peroxide plate may be used, as very sensitive voltmeters can then be used on account of the smallness of the e. m. f's. There are cases in which both curves show sharp bends, although only one plate is exhausted. The adjoining diagram has been plotted from tests of a

storage battery the negative electrode of which had a smaller capacity than the positive one. At the beginning of the discharge the negative plate has an e. m. f. of 0.1 volt against cadmium; this e. m. f. increases slowly until the plate has been converted into sulphate; after two and one half hours the e. m. f. increases rapidly to about 2.5 to 2.6 volts, when the "discharge" is continued by force, by continuing to send a current through the cell; the negative plate then becomes peroxidized. The curve has a sharp maximum when a strong development of oxygen occurs; it then drops, the development of oxygen stops, and the curve takes the shape of the normal one of the peroxide plate. On the other hand, the positive plate has, at the beginning of the discharge, an e. m. f. of 2.1 volts against cadmium, and the curve drops definitely when the plate is discharged; this normal behavior is represented first by the full line, then by the dotted line and finally by the full line. In certain cases, however, the curve drops before the capacity of the plate is really exhausted; in such cases it occurs at the same time when the curve of the other plate shows a sharp bent; but the curve of the positive plate rises again after it has met the other curve (*i. e.*, from the point where the e. m. f. of the battery is zero); it drops later again definitely when the plate is really exhausted. This behavior is represented in the adjoining diagram by the full line throughout. It looks as if the curves for the two plates influence each other. In such cases the Fuch's method gives wrong results, as it seems to indicate that the positive plate is exhausted at the front bent of its curve, which is not really the case. Only by continuing the experiment, as is done in the adjoining diagram, the real condition would become evident, but it is, of course, impossible in practice to do this. He explains this peculiar phenomenon as follows: If at the ends of a battery there are plates of the same capacity as the plates in the center, then the end plates are not yet exhausted when the plates in the center are; the lines of current then no longer go from plate to plate, but around the sides of the plates in the center, that is, there are "stray" currents; the same is the case when the contacts of a plate are bad and when it is not discharged uniformly with the other plates; such stray currents cause wrong measurements.

Although the Faure type of accumulator was considered at the time of its first invention to be a very great improvement over the older Planté type, yet experience covering many years has shown that this view was premature, as for the positive plates at least, many makers, have gone back to the Planté type. The objection to this is, of course, the cost of formation. While it may almost be assumed that most chemicals had already been tried for hastening this formation, yet PETERS with the proverbial patience of a German, has, it seems, spent an enormous amount of time and patience making an almost endless number of experiments with a very large number of chemicals, and with the thoroughness of his countrymen he seems to have made these experiments systematically and intelligently, and gives the results so that they have a real value. For a long time past he has been publishing the results in the *Centralbl. f. Accum.*, and while they have not yet been completed, they are of considerable value as they indicate that quite a number of materials will give fairly good results, while others give practically nothing. It would be impossible to give all the results here, and readers are referred to that excellent journal for the figures; a few of them, however, published in the numbers of April 1, May 1, and June 1, may be repeated here. Theoretically, 100 ampere hours could form 222 grams of peroxide of lead; the results given below were obtained with a current of 0.6 ampère and a surface of 144 sq. cm. About 35 grams of peroxide were obtained from 900 c. c. of a 15 per cent. solution of magnesium sulphate mixed with a solution of 30 grams of ammonium sulphate and 20 grams of crystallized hydroxide in 100 c. c. of water; 3.5 were formed in 30 grams of crystallized magnesium sulphate and 20 grams of sodium sulphate free from water added to 1 liter of water, the specific gravity of the solution being 1.020; about 1.10 grams, in a solution of 30 grams of bichromate of potassium and 12 c. c. concentrated sulphuric acid in 1 liter of water. The other results given in those parts are below these, but in other portions of his series of articles he gives results far superior to those given in these later parts. It may be assumed that after working as hard as he has he will not publish to the world the best results, and in this connection a small advertisement in that journal is of interest, as it states that a process for the formation is for sale, but does not state that it is his process.

The same journal of June 15, contains an account of a long series of tests made of French storage batteries to be used in the French navy. They were all discharged together in series, the discharge being stopped when the e. m. f. had fallen to 1.65 volts, and when this happened in less than half an hour the cell was not considered. After 251 discharges there were still five batteries left, four of which had pasted plates throughout, while the fifth had formed positive plates and negative pasted plates. There were altogether at the start 21 batteries by 13 different makers, 11 of which had pasted plates throughout, nine had formed positives and pasted negatives, while in one both plates were formed.

WEHRLIN AND LANGSTEIN, in the *Centralbl. f. Accum.*, June 15th and July 1st, have an article on troubles with storage batteries, in which they discuss these and give various reasons for the gradual destruction of the plates.—At the recent DUSSELDORF EXHIBITION a number of storage batteries were exhibited, some of which are described in that same journal, May 15th and July 15th.

*Other Forms of Storage Batteries.*—The lead-zinc storage battery has tempted many inventors, and descriptions of it crop out periodically, but in every case, as far as we can recall, it again vanishes as a failure; it seems to survive only as a sort of temporary storage device for very short periods, such as when used as an equalizer for brief periods of fluctuations. We fear there is little hope of this type of cell coming into practical use, but its great capacity per pound still makes it a very tempting direction for possible improvement. GABRAN, in the *Elek. Zeit.*, June 26th, describes some experiments with such a battery, accompanied by diagrams and tables. The case is made of copper, amalgamated on the inside and divided into departments by means of perforated amalgamated sheets, all of which form the negative plate, while the positives are ordinary peroxide plates, the electrolyte being, as usual, zinc sulphate and sulphuric acid. The cover and all binding posts are made of aluminum, which we fear is not a wise departure. Discharging it from 2.4 to 2.1 volts during a period of ten hours, he obtained with one battery 331 watthours for 14.3 kg. of total weight, and with three others 50.6, 81 and 72 watt hours, respectively, for 3 kg., 2.5 kg. and 2.5 kg. of electrodes alone. He experimented with them for a year and a half and finds no reason why they should not be used in practice; he claims that the copper is not attacked. While it may be true that the copper was not attacked in his cells, it is hardly likely that this would be true when the cells are used in practice, for if a single cell in a series should be overdischarged, the copper is sure to go after the zinc, which has been deposited on it during the charge, is all gone. There is another serious objection to this type of cell, which is not generally stated and perhaps not generally known. It is that the sulphuric acid is electrolyzed easier than the sulphate of zinc during the charge, which means that much of the charging current will be used to generate hydrogen on the cathodes, and this is especially the case when the contents of the zinc sulphate in the solution gets low towards the end of the charge. It is for this reason that it is almost impossible to get zinc out of a zinc sulphate solution when there is present a large amount of sulphuric acid; this wasted current will also evolve oxygen on the peroxide plates, as they will of necessity be fully charged long before the corresponding amount of zinc

has been deposited on the cathodes. We fear that this battery is a theoretically hopeless case, unless some solvent for zinc can be found which is equally effective in generating a high e. m. f., and which will decompose at a higher voltage than the zinc solution.

The *Centralbl. f. Accum.*, July 15th, contains an abstract of a patent of GAHL, who proposes to make porous silver oxide electrodes, like those used in the Jungner cell, in alkali storage batteries. He mixes fused-silver chloride with about 15 per cent. to 20 per cent. of lead chloride, and then removes the chlorine by using the plate as a cathode in an alkaline-hydrate solution; then removing the lead by using the plate as an anode in another solution, which is not given, the silver being at the same time oxydized.

*Standard Cells.* The very exhaustive series of tests of the Clark and the Weston cells, conducted more especially at the Reichsanstalt, have greatly increased the confidence which one can now have in their constancy and reliability. In fact, they are now, together with the standard resistances, the real basis of exact electrical measurements; they can now be made to be exact and uniform to within 0.01 per cent. and will remain constant within this limit. Among the recent papers on such cells is another emanating indirectly from the Reichsanstalt, by JAEGER, who has devoted much time at that institution to a study of these cells; it is a Bunsen Society paper, published in the *Zeit. f. Elektrochemie*, July 24th, and abstracted in the *Centralbl. f. Accum.*, July 15th. He first discusses at some length the Clark cell with saturated electrolyte, and an excess of solid zinc sulphate, several forms of which he describes and illustrates. At 15° C. the generally accepted mean value of the e. m. f. is 1.433 volts, which is in exact agreement with Carhart and Guthe's determination. The formula accepted by the Reichsanstalt for the e. m. f. $E$, in international volts at the temperature $t$ degrees C., is $E = 1.4328 - 0.00119\ (t-15) - 0.000007\ (t-15)^2$. He briefly discusses the changes taking place in the Clark cell at a temperature of 30°, which are interesting from a physicochemical point of view. As the high temperature coefficient of the e. m. f., which is about 0.08 per cent. per degree, necessitates a troublesome correction, Weston and Carhart have proposed using a dilute zinc sulphate solution; for instance, saturated at 0° C., in the temperature coefficient is thereby diminished to one-half, but such cells have not been defined with sufficient precision. He then mentions briefly the Helmholtz calomel cell, consisting of zinc, zinc chloride, calomel and mercury, but it is not suitable as a standard cell, because different cells do not give uniform values; the calomel does not seem to be a sufficiently good depolarizer. The Weston cadmium cell is an excellent standard cell and has a very small temperature coefficient; he believes that in course of time it will entirely replace the Clark cell. The Weston Co. use a dilute solution of cadmium sulphate, saturated at 4°, while the measurements made in the Reichsanstalt were nearly always made with a saturated solution, with an excess of solid crystals. For a cell with dilute solution the temperature coefficient is practically equal to zero within the ordinary temperatures; the e. m. f. is 1.0191 international volts. The e. m. f. $E$, in international volts of the cell with saturated solution and crystals, is given by the formula $E = 1.0186 - 0.000038\ (t-20) - 0.00000065\ (t-20)^2$. At 4° C. both types of cells have nearly the same e. m. f.; neither shows a lagging of the e. m. f. behind the temperature, a fact which is self-evident for cells without crystals; there is no cracking of the vessel at the negative pole on account of the amalgamation of the platinum wire and there is no development of hydrogen. The cadmium amalgam must have between 5 and 14 per cent. of cadmium. Contrary to some experiments by others, the very numerous measurements of the Reichsanstalt have not shown any irregular behavior whatever of the Weston cells at 15°, provided a cadmium amalgam below 14 per cent. was used. From measurements extending over several years, the following values of the ratio of the e. m. f's. of the Clark and the Weston cell were found: Clark at 0° to Weston at 20° 1.42280; Clark at 15° to Weston at 20° 1.40669. These ratios have not changed by more than 0.0001 in four years. A standard cell must represent a reversible chemical system and would theoretically have the best form, if the electrolyte is also present in solid form. The depolarizer is best when solid and a good conductor. When mercurous sulphate is used, there are complications due to its solubility.

There was another article, also a Bunsen Society paper, in the *Zeit. f. Elektrochemie*, July 24th, by LUTHER, in which he discusses the question of the degree of chemical purity of the electrolyte in order to obtain the required exactness. He considers a Clark cell with saturated zinc sulphate solutions and zinc sulphate crystals, and investigates, by a thermodynamical several years, the following values of the ratio of the e. m. f's. be when the zinc sulphate solution contains an addition, say, of glycerine. He imagines two Clark cells connected against each other; that is, positive connected with positive, the electrolyte of the one being pure and that of the other containing glycerine. This system is imagined to first give out current and then to be brought back again to its initial condition by means of isothermic distillation. From the laws of thermodynamics, it then follows that the e. m. f. of this system, namely, the difference between the e. m. f's. of the two cells, depends only upon the ratio of the vapor pressures of water of the electrolytes of the two cells, a conclusion which he then confirmed experimentally. One Clark cell contained an impurity of 50 per cent. by volume of glycerine, while the electrolyte in the other was pure; the difference of the e. m. f's. of the two cells was found to be 0.00744 volt at 25°, from which he obtains, by means of his theory, the ratio 1 to 1.09 for the vapor pressures, while it was found experimentally to be 1 to 1.10, thus confirming his theory. He draws the following interesting conclusions from his theory: if the solid crystals in a standard cell with saturated solution (corresponding to the zinc sulphate crystals in a Clark cell with saturated zinc sulphate solution) are free from water of crystallization, then the e. m. f. must be independent of impurities and of the solvent. He is trying to devise a practical standard cell in which this condition is fulfilled.

## GENERAL AND MISCELLANEOUS.

*Silver Voltameter.*—The sources of error in the silver voltameter were the subject of careful research by the Reichsanstalt some years ago, and it was then shown that for precise measurements very great care must be taken, as the sources of errors are quite serious, so much so that it really becomes quite difficult to use it, and the standard cell, combined with the standard ohm, therefore gives a more reliable ampère. LEDUC has recently presented a paper to the French Academy, published in *Comptes Rendus*, July 7th; *L'Eclair. Elec.*, July 26th; *L'Ind. Elec.*, July 25th, and Lond. *Elec.*, August 1st, in which he discusses some of these sources of error. One lies in the change produced in the acidity or alkalinity of the solution, some observers claiming that it becomes acid, while others say it becomes alkaline; this, he shows, is entirely a question of circumstances, such as the rapidity of the electrolysis. The nitric acid which is generated is electrolyzed at the same time as the nitrate of silver itself, but no hydrogen is evolved, as it precipitates silver from the nitrate and also forms a complex compound with nitrogen and hydrogen. There is popular misapprehension that the deposit of silver on the cathode is corroded by the solution, but he shows, by careful weighings, that such a corrosion does not exist. On the other hand, there must be an appreciable polarization of the cell, which is usually supposed to be negligible; he estimates it to be 0.03 volts. He mentions the fact that if a silver plate is put into the cell, but not connected to the circuit, it shows a slight loss of mass, whereas there is no such loss when a silver needle is used instead; the loss in the case of the plate depends upon the way in which it is immersed, being greater when it crosses the current.

## CORRESPONDENCE.

### THE PROSPECTS OF THE ELECTROCHEMICAL INDUSTRIES.

*To the Editor of the Electrochemical Industry:*

SIR: The year 1902 will mark an epoch in the development of practical electrochemistry in the United States. Heretofore, patient experiment, close thinking and hard work on the part of individuals have resulted in the commercial success of certain electrochemical establishments. All that has been done has been the result of unorganized effort and American "get-thereness." There have been some bad wrecks and on the shore are seen the hulks of once fair craft, stranded because of the lack of knowledge of previous failures. For "by our failures do we learn rather than by our successes."

At the present day, we see several of our universities and technical institutions offering courses designed to furnish their students special knowledge of electrochemistry. We also see the founding of a society which brings the practical men and the theoretical men together, and where also an enlightened self-interest has caused frank discussions of practical problems to be in order.

Finally, we witness the start of a technical journal with good auspices, which journal will chronicle the progress of this new applied science in its vigorous youth—at the same time helping the growth to be normal, yet rapid.

That such a field now exists is to my mind shown clearly by the low rates that hydraulically generated power can be bought at the present time. Such inducements are offered for electrochemical works to locate, and the terms are so attractive, that one is forced to the conclusion that these large plants will to expand and to sell power in large amounts at a small profit. The potential supply certainly exceeds the possible demand.

In any electrochemical process, be it electrolytic, electrothermal or a combination of the two ways, the cost of power is a large fraction, often 25 to 90 per cent. of the entire cost. The old electrochemical theory of Berzelius is so modified that we know that variations in chemical potential are strictly proportional to variations in electrochemical potential. For example, lead is easier reduced than zinc, zinc than magnesium, magnesium than sodium. In their electrolytic potential these metals stand in the same relative positions. Similar facts can be stated in regard to the non-metals, e.g. fluorine, chlorine, bromine and iodine.

Accordingly, it can be asserted that any metal can be reduced or any compound formed by using the corresponding potential. This is not strictly true, but in an approximate manner, because uniform conditions cannot be maintained. Easily studying the conditions of temperature, current, electrolyte, etc., it may be said that the majority of chemical products can be produced by electrochemical means. The electric furnace has also put at the disposal of the electrochemist or metallurgist such temperatures that many chemical changes can be effected. "Electrochemistry" is the name to be given to the resulting thermal potential.

Cheap power is, of course, the foundation stone on which the electrochemical Archimedes is to carry on commercial success in the manufacture of chemicals. Fuels, labor, discoveries of materials, convenience to markets, easy questions to be solved, will be settled as the great power plants become more and more the industrial centers. The United States has in these points a greater possibilities for development than any other country, because they are near at hand to our water-ways and not too far distant from present centers. The falls of Niagara are commercially in touch with New York. The falls of Zambesi are commercially remote from London. The law of inverse squares holds here in business as in gravitation.

The utilization of this power is the "electrochemical industry." The journal bearing that name must co-ordinate incubate ideas, simplify practice, extend our knowledge of the [illegible] We [illegible] from the Pierian [illegible] to the [illegible] achievement. The [illegible] of the ELECTROCHEMICAL INDUSTRY [illegible] to feel we believe that it will fill the long want.

Yours very truly,
WOOLSEY McA. JOHNSON.

New Brighton, N. Y.

## BOOK REVIEWS.

ELEMENTARY PRINCIPLES IN STATISTICAL MECHANICS. DEVELOPED WITH SPECIAL REFERENCE TO THE RATIONAL FOUNDATION OF THERMODYNAMICS. By J. Willard Gibbs. New York: Chas. Scribner's Sons, 1902. 207 pages. Price, $3.00.

This is one of the volumes of the "Yale Bicentennial Publications," issued in connection with the bicentennial anniversary of Yale University, "as a partial indication of the studies in which the University teachers are engaged," and Old Yale may be proud of J. Willard Gibbs.

Prof. Gibbs' studies in thermodynamics and in the application of thermodynamical methods to problems of physical chemistry, were begun many years ago. The work that Gibbs has done in this line in his younger years, was ahead of the time and, moreover, was of such a highly theoretical and analytical nature that it appealed to only very few, and was soon forgotten, until in the last ten or fifteen years the rapid and enormous development of physical chemistry in general and especially of electrochemistry set in. Attention was then directed to Gibbs' early work, especially by German scientists. Planck, in starting his valuable thermodynamical investigations, followed closely the footsteps of Gibbs, and Ostwald translated the early important papers of Gibbs into German. It soon became apparent that many interesting results obtained independently by new investigators had been anticipated many years ago by Gibbs. Since then Gibbs' name has become more popular, and as an indication that he is now well known even in his own country, we may recall the hearty applause that followed a few well chosen words spoken in his honor by Prof. Carhart in a discussion of a paper at the inaugural Philadelphia meeting of the American Electrochemical Society.

This latest book of Prof. Gibbs is of the same highly theoretical nature as his former work. To read the advanced student it is very difficult reading, as it requires a thorough knowledge of the higher mathematics and of mathematical physics. "Statistical mechanics" [illegible] a branch of mathematical physics which has [illegible] to explain the [illegible] and of which Clerk-Maxwell and Boltzmann are the [illegible] founder. Prof. Gibbs in the present book [illegible] statistical mechanics [illegible] to thermodynamics, [illegible] done in his former papers, but in such a way as to show in how ways [illegible] and thermodynamical principles [illegible] new light.

While the work is of the highest value from a theoretical point of view and will be appreciated by the advanced student, it can hardly be said to be practical in the ordinary sense of the word. It cannot be overestimated that the theory of electrochemistry of the future will be based on the principles of thermodynamics. But to make such a theory a practical tool for the consulting engineer, it will be necessary to find a rational foundation of thermodynamics itself. From the point of view, Prof. Gibbs is undoubtedly right to attempt to put such a foundation on statistical mechanics, but others look at this from a different standpoint. We are still far from having established thermodynamical terms and methods; to mention only one example we may quote James Swinburne's recent attempt to attack the problem from the electrical point of view; he is primarily an electrical engineer, so he tries to develop the principles of thermodynamics in a way strictly analogous to

the theory of electricity. From the point of view of an electrical engineer this is a "rational" starting point, but whether it will lead to a complete and correct demonstration of thermodynamics, it is for the future to show.

Prof. Gibbs' book is divided into 15 chapters. In the first he gives the general ideas and discusses the "principle of conservation of extension-in-phase." In the second and third chapters he applies this principle to the theory of errors and to the integration of the differential equations of motion. In the fourth and following chapters he considers statistical equilibrium and conservative systems. He treats especially of what he calls the "canonical" distribution, in which the index of probability is a linear function of the energy. While in other chapters he often touches briefly on thermodynamical analogies, the fourteenth chapter is devoted entirely to this. In the last chapter he deals with systems composed of molecules; he introduces this supposition at the end of the book, because he wants to separate very decidedly the purely thermodynamical laws from those special modifications which belong rather to the property of matter.

Transactions of the American Electrochemical Society. Vol. I. Philadelphia: Inaugural Meeting, 1902. Published by the Society in Philadelphia. Price, $3.00 in cloth; to colleges, libraries, societies and journals, $2.00; to members, free. 250 pages; illustrated.

This is the first volume of the transactions of this new national society, which was formed in Philadelphia last April at the suggestion of a few electrochemists in Philadelphia, who had been meeting informally for several years to discuss electrochemical subjects. A preliminary meeting of the more prominent electrochemists in this country was called in Philadelphia last November to discuss the question of founding such a society, and it was decided that if 75 members could be secured the society should be founded and a formal meeting arranged for. While some of those who attended the preliminary meeting, and a number of those who sent their opinions in writing, had grave doubts about the advisability of starting such a society, the majority were of a different opinion. The fact that in a short time about 350 members were secured, showed that the time was ripe for the formation of such a society.

The present volume consists chiefly of the 20 papers that were read at the first formal meeting. These are published in full and are followed by the revised stenographic report of the discussions, which latter are in a number of cases extremely interesting. A number of these papers are illustrated, some of them with half-tone inserts. It would require much space to give even a brief review here of the papers themselves; it suffices to say here that they included a wide range of subjects on industrial, theoretical and experimental work or subjects, and on instruction in electrochemistry, many of them are of considerable interest. With perhaps one unimportant exception, these papers are all new and original matter. The intention seems to be to publish a volume after each meeting, the number of meetings depending upon the number of papers which can be secured, and other considerations.

A somewhat peculiar and striking color has been chosen for the cover of these *Transactions*, evidently for the purpose of attracting attention, as we do not remember having seen any book or journal with a cover of the same color.

Besides the papers this volume contains a portrait of the first president, Joseph W. Richards, some introductory remarks by the president, a historical sketch of the formation of the society, the proceedings of the business meetings, the constitution, and the catalogue of the members; those in the present list have the honor of being called charter members. The general make-up of the book is about like that of the transactions of other national societies and is very creditable to such a young society. These transactions promise to become important in the literature on electrochemistry.

## REGULATING RHEOSTATS.

While rheostats are a necessary accessory in nearly all the different branches of electrical engineering, they are of special interest to electrochemical engineers for two reasons: first, because successful operation of electrochemical processes generally requires that the voltage and the current necessary for a special purpose are maintained with great exactness during the operation; second, because the use of relatively very high currents for electrochemical processes has made a special design of rheostats indispensable for such purposes.

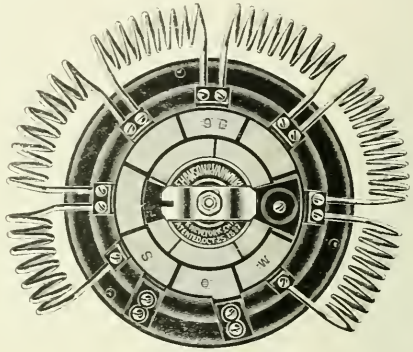


FIG. 1.—DYNAMO RHEOSTAT.

For instance, any electroplater knows that different voltages are required to operate successfully different kinds of solutions. If the correct conditions are not maintained during the process of electroplating, the results are unsatisfactory; if the current becomes too great (*i. e.*, if the e. m. f. applied at the terminals of a given electroplating tank is greater than required) there is a tendency to burn and blacken the work to a marked degree.

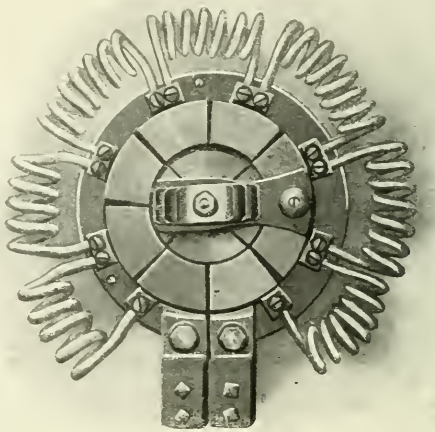


FIG. 2.—RHEOSTAT FOR ELECTROCHEMICAL PROCESSES.

The accompanying illustrations represent three rheostats made by the Hanson & Van Winkle Co., of Newark, N. J. The rheostat shown in Fig. 1 is made to carry from 10 to 250

amp. and is used for various purposes, especially in connection with dynamos; in the smaller sizes for field regulation and in the larger sizes for carrying the main current.

Figs. 2 and 3 show rheostats for use in electrochemical processes and especially in electroplating. The rheostat, Fig. 2, carries currents from 800 to 1,000 amp. without excessive heating; the duplex rheostat, Fig. 3, carries currents of 2,000 amp. It has sufficient wire to allow of toning down the highest electromotive force used in electroplating. Enough segments are used to reduce the e. m. f. to two volts and at the same time avoiding any excessive heat and danger from fire. All the segments, lever arms and connections are made of a special copper casting, and their calculations are all based on a carrying capacity of 1,000 amp. per square inch. These are mounted on an iron base, which is insulated from the copper segments with a specially prepared vulcabeston insulating material, heat or moisture having no effect upon it. The rheostats are then mounted on marbleized slate and the whole is then mounted on a handsomely polished oak base board. As there is always a great deal of moisture and acid fumes in a plating room, the resistance coils are given a heavy deposit of zinc, which amply protects them from rusting. These coils are made from a special resistance wire, which

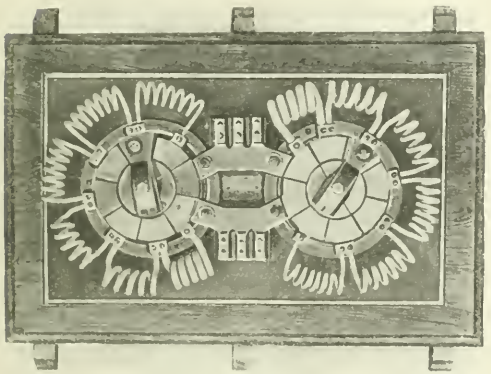


FIG. 3. MULTIPLE RHEOSTAT.

is carefully tested for its resistance and carrying capacity, and graduated on each rheostat from a light to a heavy wire according to the current it has to carry, and at the same time giving sufficient reduction in voltage for a large or small amount of work.

The multiple rheostat, Fig. 3, has the advantage that one of the resistances can be thrown out of the circuit by moving the lever arm on the off segment. This can be done when a current of 1,000 ampères or less is being used. By this method four times the resistance is obtained. As the load is increased the other rheostat is thrown in the circuit. This size of rheostat is used in the main line to control the voltage of several large tanks, or very large galvanizing and acid copper solutions, also for special purposes where large currents are to be used.

The Hanson & Van Winkle Co. have for many years installed numerous successful plants for electroplating. Their stock of apparatus and accessories, required for cold galvanizing plants, is complete. They also carry in stock chemicals, polishing lathes, polishers' and buffers' supplies, grinding machinery, plating dynamos and lacquers.

## EXTERNAL SHUNT AMMETER.

Special electric installations require special measuring instruments. The rapid and enormous development of high-tension power transmission in recent years has necessitated special devices and designs for instruments to be used at very high voltages. On the other hand, in electrochemical industries it is the current which is abnormally high; and, as for electrochemical processes, it is generally essential to keep the current strength under control. It is important to use ammeters, which enable an exact measurement of very large currents and which, at the same time, consume only a small amount of energy.

The accompanying illustration shows a Weston ammeter of the "external shunt" type, which involves a method of action quite different from that of the usual type of ammeter.

The difference of potential between two points on a conductor is directly proportional to the current passing through the conductor. If, therefore, the resistance between two points of a certain conductor is known and we want to measure the current which passes, a voltmeter connected at these points can be used to measure the current. Or if we know, in one case only, the potential difference which exists between the two points when a known current passes, then we can find in any case the current by measuring the potential difference. For example, if a voltmeter is connected to two points on a conductor, and it is known that with 1,000 amp. passing through the conductor the potential difference between these points is 0.01 volt, then a reading of 0.0155 volt on the voltmeter indicates that the current at that moment is 1,550 amp.

To make this method of measuring the current strength practical it is essential that the voltmeter used is sufficiently sensitive, so that a potential difference between the binding posts amounting to a small fraction of a volt will cause the pointer to move across the entire scale.

EXTERNAL SHUNT AMMETER.

It must be remembered that any drop of potential involves a loss of useful energy, and consequently there should not exist a great difference of potential between any points of a conductor on the same side of a translating device. The cross section of all conductors should be large enough to reduce this loss as much as is practical. The limit is reached when any increase in efficiency obtained by increased cross section of the conductor would be overbalanced by the increase of interest on the cost of the conductor.

The Weston shunt ammeter is, in fact, a voltmeter of high sensitiveness which gives a full scale deflection with 0.03 volt between its binding posts. In any plant such a small potential difference between points of the conductor will be found. In case the cross section of the conductor is based on one square inch copper per 1,000 amp., only a length of about 4½ feet would be required.

It will be seen that the conductors have not to be lengthened, bent or specially shaped in order to accommodate the ammeter, but that the instrument proper can be connected to two points of different potential by thin connecting wires. The maximum current flowing through the instrument never exceeds 0.06 ampères. Of course these connecting wires are an integral

...therefore, when ...not be altered.

...electrical plant consist...ance considerably with ...preferable not to use a part ...instrument, but to insert ...alloy having a small ...coefficient.

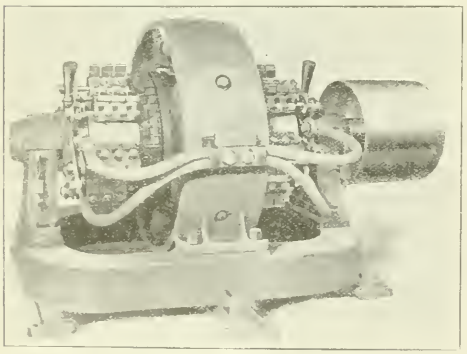
This has the further advantage that the combination of instrument and shunt can be properly adjusted in the laboratories of the manufacturer.

...expenditure for copper and labor required for installa... is reduced by shunting the instrument, and a decrease in ...expenses is effected by the extreme sensibility of the ...instruments. As already stated the Weston ammeter ...a potential difference of 0.03 volt between the binding ... takes 0.00 amp. for full scale deflection. It con...ture, not more than 0.018 watt, whereas, most, if ...meters of other types consume from 800 to 1,000 ... when measuring a current of 1,000 amp. Especially ...powerful currents are used, these savings often exceed ...total cost of the instrument.

The Weston Electrical Instrument Co., Waverly Park, N. J., manufacture these instruments in different styles of any required capacity, with and without illuminated scale, and also make voltmeters ranging from a fraction of one volt for full scale deflection up to 10,000 volts, and higher. Their line of portable testing instruments is complete and covers all special requirements met with in the different branches of electrical engineering.

## ELECTRO-PLATING DYNAMOS.

Twenty-one years ago, in a building on Market street, Hartford, Conn., Arthur E. Eddy began the manufacture of dynamos for electroplating, and from that time the name "Eddy" has been accepted by users of this class of apparatus as guaranteeing the quality both with regard to con...



...PLATING MACHINE.

...operation ...with all other forms of electrical ...machinery, the modern dynamo for electrolytic work is very different in design from the first ones, yet that they were good in every way is proved by the fact that several of the eleven first made are in commercial use to-day.

The maintenance of the enviable reputation of the "Eddy" machines is due to the fact that great care has been exercised in their design, the results of both theoretical and experimental researches being fully utilized.

The modern dynamo for electrolytic work must be simple, durable and efficient, maintaining its voltage, and running sparkless under charge of load without the necessity of shifting the brushes, and in the above particulars the "Eddy" machines are believed to be unsurpassed. Several years ago the use of the three-wire system in connection with machines of this class was found desirable, and double-commutator machines were designed. The saving in line loss and convenience of having two voltages available, more than com...

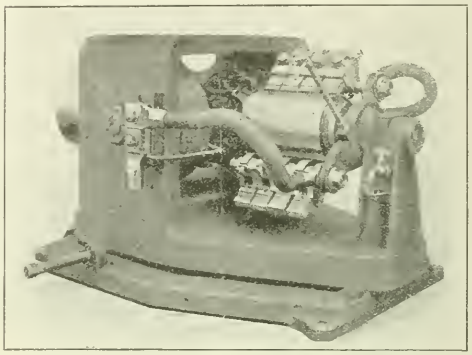


FIG. 2.—BIPOLAR ELECTROPLATING MACHINE.

pensates for the slightly increased initial cost. That low voltage, high-current machines without commutators could be made was also realized, and such a machine is in operation to-day, but the output in current and the necessary weight were so great that very little demand for them was to be expected. The accompanying illustrations show some of the machines as above described.

Fig. 1 shows the double-commutator, six-pole type, each

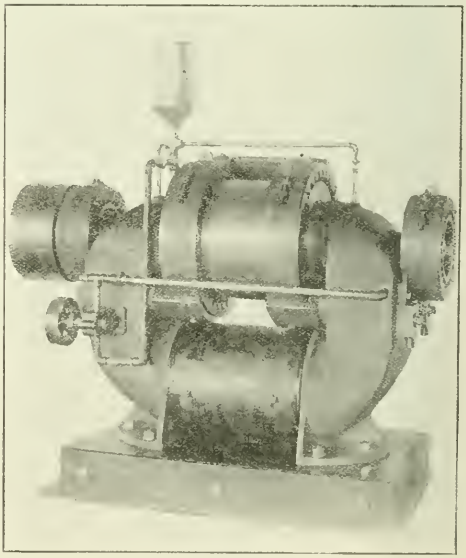


FIG. 3.—UNIPOLAR ELECTROPLATING MACHINE.

armature winding being independent, and the machine so made that they may be connected in series or parallel, giving either the sum of their voltages with the current of one, or the voltage of one and the current of both. Five or more volts per commutator is the ordinary practice, depending upon con...

dynamos. Seven and one-half, 10 and 30 K. W. machines have been made of this type.

Fig. 2 shows the latest two-pole type, of which 5, 20 and 75 K. W. machines have been made.

Fig. 3 shows a unipolar or continuous-pole machine, designed for 2 volts and 6,000 amperes, and [illegible] when tested 9,000 amperes.

Eddy machines for electrolytic work have been made up to a capacity of 150 K. W., and will be made in future by the Eddy Mfg. Corporation, Windsor, Conn.

## PERSONAL.

PROF. F. HABER, of the Institute of Technology, of Karlsruhe, Germany, and Prof. R. S. Hutton of Owens College, Manchester, England, are visiting this country to study the development of the electrochemical industries in the United States. Both gentlemen will attend the meeting of the American Electrochemical Society, at Niagara. Prof. Haber is the official delegate of the German Bunsen Society (which is the German branch of the German Electrochemical Society). Prof. Haber is the author of an excellent German treatise on industrial electrochemistry from a theoretical basis.

## INDUSTRIAL NOTES.

THE [illegible] BARIUM CO. are erecting a [illegible] brick warehouse, 60 by 120 ft.

THE NORTON EMERY WHEEL CO. are about to install [illegible] additional furnaces for the Baker-Bisson process, which will increase their capacity 50 per cent.

V. J. ROSSI has been running his electric furnaces during July and August, producing ferro-titanium alloy for experimental use in casting car wheels. During September operations will be discontinued, awaiting the results of the experiments.

THE CARBORUNDUM CO. are extending their furnace plant so as to increase its capacity 50 per cent. The new Acheson type furnaces will require an additional 1,000 horse power, and will be ready for operation as soon as the power company can furnish the power.

THE ELECTRICAL LEAD REDUCTION CO. are designing reduction apparatus for the whole of their large cell room, which has heretofore contained only one-tenth of its cell capacity, and expect before the end of the year to be running full capacity at a greatly decreased cost of operation.

THE NIAGARA POWER CO. have their first ten units of 5,000 horse power fully occupied, and several works are awaiting the opening of the new power house to enlarge their capacity. The next 10,000 horse-power of the new plant is being rapidly put in place, and October 10th is the date now set for turning on this current.

THE ACKER PROCESS CO. are erecting scrubbing towers at the works of their bleaching powder plant, to absorb the residual chlorine. The gases from the lime chambers carry out 0.01 to 0.05 per cent. of chlorine, which at present escapes into the air, but will in future be completely absorbed by passing through the scrubbing towers, where it comes in contact with coke saturated with water.

THE ACME FIBRE PRODUCTS CO. are erecting a two-story building, red brick two-story building, 50 by 120 feet, adjacent to the upper works of the Patterson Raceway Co. The building is to be used as a machine shop, to install the small choke coils which are required in each house numbers for the apparatus they use. The large 2,000 horse power plant which is in contemplation, and in which the apparatus is to be installed, will be [illegible] adjacent to the present plant on ground [illegible] for further extensions.

[illegible]

[illegible]

[illegible]

## INTERNATIONAL CONGRESS FOR APPLIED CHEMISTRY.

[illegible]

## DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

*Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.*

This digest of electrochemical United States patents, prior to July, 1902, will be essentially one by classes, that is to say, it will set out for comparison those devices which have the same object, or those methods which seek the same result. In each class the patents will be arranged chronologically. It is the intention to make this digest complete in the sense of covering every point which is touched upon in the original specification. The first class to be dealt with comprises the patents on the electrolysis of sodium cloride with mercury cathodes.

271,900. February 6, 1883; A. L. Noll, Brussels, Belgium.

Gas retort carbon anodes slowly revolved over a quiescent layer of mercury, 1 cm. deep, resting on horizontal sheet-iron bottom of closed vessel.

Electrolyte, sodium chloride maintained saturated by crystals in perforated receptacles.

Amalgam drawn off while still fluid and distilled for sodium, or for rich amalgam, or converted into caustic soda by warm water.

307,463. November 4, 1884; A. S. Hickley, Montreal, Can.

A secondary battery with carbon anode, mercury cathode, sodium chloride or potassium chloride electrolyte.

Amalgam is formed in charging, chlorine escaping; in discharging, amalgam acts as anode.

Cell provided with incomplete partition at end, whereby part of the mercury may be withdrawn to regulate battery, or all may be separated from electrolyte to stop action.

307,462. November 4, 1884; A. S. Hickley, Montreal, Can.

Improvement on above.

Mercury contained in superposed stone trays and contact made by immersed wire netting.

Wooden grate in upper part of each tray supports a small stool, which serves to support and space the tray next above.

Anode-broken carbon packed around and between trays, contact being made by carbon rods.

Electrolyte sodium chloride solution.

350,040. January 25, 1887; A. S. Hickley, Montreal, Can.

Cathode mercury in depression in cell.

Anode, a carbon block above the mercury; supplemental anodes of broken carbon surround the mercury-containing depression.

Continuous flow of sodium chloride solution through cell and saturation chamber.

To remove amalgam employs a sieve; the thick amalgam is pressed to remove surplus mercury and packed in air-tight vessels. Subsequently used in primary or secondary batteries.

501,783. July 18, 1893; E. Hermite, Paris, and A. Dubosc, Rouen, France.

Mercury flows down over inclined surface of amalgamated copper, in close proximity to parallel platinum anodes.

Passes into trough, where it is allowed to stratify under carbon disulphide. Richer amalgam drawn off into separate vessel, decomposed by water and mercury returned.

Applicable to any solution of an alkali or alkali-earth metal, as Na, K, $NH_4$, Mg, Al.

In oxidizing, cell may form bases (with water), or any desired salt, as carbonates, by passing carbon dioxide through the water.

513,661. January 30, 1894; C. T. J. Vautin, London, Eng.

Finds that surface tension of mercury will prevent it from passing through perforations corresponding to 60-mesh sieve, if not subjected to shock and no considerable head.

Mesh of non-conducting material, as silk, perforated celluloid or vulcanite, or enameled metal, placed horizontally. Anodes at side and provided with chlorine-collecting hoods.

Sodium amalgam transferred through the mercury and oxidized by supernatant water.

Also oblique arrangement, the mercury cathode being arranged in terraces.

Also vertical arrangement, perforated or slotted iron plate, covered with vulcanized rubber. Mercury retained in perforations by mesh as above.

518,135. April 10, 1894; H. Y. Castner, London, Eng.

Apparatus for carrying out process of U. S. Patent 528,322.

Cell having two anode compartments and one intermediate cathode compartment, is supported on two adjustable knife edges and rocked by eccentrics.

For ⅛-inch depth of mercury the eccentrics have a pitch of about ¼ inch.

525,555. September 4, 1894; A. Sinding-Larsen, Christiania, Norway.

Mercury caused to flow by paddles through annular channel, passing at one point beneath a rotating anode, which is in an offset from central compartment, and separated from annular trough by incomplete partitions, the mercury acting as a seal.

Annular trough filled with water and central chamber with offset for anode with sodium chloride solution.

Cathode connections to mercury.

528,153. October 30, 1894; T. Drake, Huddersfield, Eng. Eng.

Porous pot closely wrapped with amalgamated wire gauze or equivalent cathode.

Anodes of carbon cast in lead cover in pot.

Sodium chloride solution in pot and water outside, both circulated.

528,322. October 30, 1894; H. Y. Castner, London, Eng.

Mercury cathode circulated (by pump or stirrer with radial blades) between anode compartment, containing sodium chloride solution, and cathode compartment, containing water.

Supplemental cathode and electrical connections to reduce the required electromotive force.

546,348. September 17, 1895; W. A. Rosenbaum, Montclair, N. J.

Body of mercury in annular trough. Annular bell, divided by transverse partitions, forming alternate decomposition and oxidation compartments, rests in trough, mercury operating to seal compartments.

Sodium amalgam formed in decomposition cells, annular bell rotated and amalgam oxidized by water.

May rotate bell continuously or oscillate.

Separate anodes and cathodes in oxidation cell, anodes being close to surface of amalgam to facilitate oxidation.

Ribs to retain mercury quiescent.

546,353. September 17, 1895; A. Sinding-Larsen, Christiania, Norway.

Vertical annular chamber contains rotating ring of amalgamated, tinned sheet iron, which, at lower portion, passes through the mercury cathode.

Center forms anode chamber, containing also feeding chamber.

Amalgam, as formed, is carried down through mercury by a small amalgamated roller, taken up by revolving ring and exposed to water in the annular chamber.

Automatic device for withdrawing caustic soda from latter at predetermined density.

Also a horizontal arrangement in which ring is conical, and amalgam is caused, by centrifugal action, to travel upward in a thin film.

[*The digest of the patents of this class will be continued in the next issue.*]

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## THE NIAGARA FALLS MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The Niagara Falls meeting of the American Electrochemical Society, a full report of which is given in this issue, has proved the splendid success which had been hoped for. All who attended it will long remember it with pleasure, and we may hope that the success of this meeting will prove stimulating not only to the young society, which may well be proud of its work, but also to the great industry which the Society represents.

Swiftly advancing, indeed, like the electrochemical industry, has been the career of the American Electrochemical Society in the first half year of its life. Founded in Philadelphia on April 3, 1902, it is just six months old; it has now more than 400 members, and has held two general meetings, both of which were extremely well attended; at these meetings there were read and discussed together about 40 papers on various important and interesting subjects. There were well-meaning scientists and engineers who first opposed the foundation of this new society as being superfluous and detrimental to the interests of the older sister societies—the American Institute of Electrical Engineers and the American Chemical Society—and it is a splendid proof of the value of the young society's work that its strongest former opponents now join it and confess that the new society fills a need.

The American Electrochemical Society has certainly secured members from both the other societies, without being detrimental to their interests in any way—on the contrary, while the watchword of the new society is naturally differentiation and specialization on the distinct limited field of electrochemistry, it has broadened the mind of both electrical engineers and chemists; it has brought them together, and it is, indeed, now the connecting link between the American Institute of Electrical Engineers and the American Chemical Society. By attracting the best members of these two societies and bringing them into personal contact with each other, it stimulates original thought on new lines; surely, the electrical engineer can always learn something from the chemist, and vice versa. But besides this, the American Electrochemical Society has brought together the electrochemical specialists of industry and science and the exchange of opinion between both classes of electrochemical workers has already proven to be of considerable value to both.

The quality of the papers read at the two meetings has been unexpectedly high. Electrical engineers, chemists and physicists of established reputation have contributed papers; and with them there are the young, energetic electrochemical workers pushing to the front. Youth is, indeed, the keynote of the success of the new society. It is only natural that in such a young industry and science there is no uniformity of opinion; there are no standardized methods, and there is no

orthodox faith. It would be an unfavorable symptom if it was different. Just for that reason, it is of the highest importance that there should be animated discussion, there should be freedom of speech even if sometimes a speaker hurts the scientific feelings of others, by attacking their pet theories. The American Electrochemical Society is no mutual-admiration society; it is a society to exchange views, to disseminate among the members all the information known, and to stimulate new thought and new work. In regard to the discussion of the papers, there is room for improvement; the value of the discussion would be considerably enhanced if the papers were printed and distributed in advance of the meeting, so that it would be possible for the members to study them carefully and prepare what they have to say in the discussion. We understand such a plan has already been taken into consideration by the board of directors of the Society, and we trust it will be carried into effect. Surely the money spent for this purpose will be well spent.

Lack of space does not permit here a detailed analysis of the papers read at Niagara; longer abstracts of all of them will be found on the following pages. It may suffice to say here that at both meetings, at Philadelphia and at Niagara Falls, the programme contained papers on subjects of the greatest variety; indeed, in looking over the titles, one is astonished to find how large the field of electrochemistry really is. While professors and scientific workers are slightly in the majority, it is extremely gratifying to see that the practical electrochemical engineers also have contributed their share, and have not hesitated to describe their processes and to tell of their troubles.

Before the Society was founded, the opinion was repeatedly expressed that the secretive methods of the electrochemical manufacturer would be the stumbling block; that the practical engineer might become a member, but would never read a paper. It affords great satisfaction to state that this fear was unfounded. An unexpectedly large number of papers have been read at the two meetings by industrial electrochemists; all of these papers proved to be of great interest, and will form a very valuable part of the transactions of the Society. It is gratifying to see that the practical engineers themselves recognize that a frank statement of what they are doing can never hurt them. Publicity always has been and will be a spur to progress. In this connection we may mention here the names of those electrochemical companies which courteously opened the doors of their workshops to the members and guests of the Society. They were: The International Acheson Graphite Co., the Carborundum Co., the Electrical Lead Reduction Co., and the Atmospheric Products Co.

It is also gratifying to see that the subjects of the papers read and discussed at the meetings were not limited to electrochemistry in the narrowest sense, but repeatedly dealt with problems of physical chemistry. Indeed, an electrochemical problem is often only a special case of a more general problem of physical chemistry. This is why the pioneer society in the field of electrochemistry, the old German Electrochemical Society, has recently changed the name into German Bunsen Society for Applied Physical Chemistry. Nobody would probably recommend an analogous name for the American Electrochemical Society. But the policy is to be recommended, not to exclude the discussion of problems of physical chemistry. For the electrochemist needs knowledge of the principles of physical chemistry, and it is the duty of a society devoted to the interests of electrochemistry to acquaint its members with the great problems of physical chemistry in general, which may have an important influence on the developments of industrial electrochemistry in the future.

Finally, we may say that a good deal of the success of the new Society has naturally been due to the personal and social element, and to the free intercourse between the members. It is perhaps not accidental that the Society was formed in Philadelphia. The old Quaker city is often called the city of the homes. Electrochemists in Philadelphia first felt that, as electrochemists, they had no home; that, as electrochemists, they were not at home in any of the old large national societies. And when they appealed to the electrochemical engineers and scientists of the country, the hearty and enthusiastic response from all sides disclosed the fact that this was a general feeling all around. The electrochemical engineers and scientists, representing a rapidly-progressing industry and science in the strength of its youth, wanted to have a society for themselves. Thus the American Electrochemical Society was founded. While the social intercourse at the Philadelphia meeting was very pleasant, and many workers in the electrochemical field came there for the first time into close contact with each other, the Niagara Falls meeting was a still greater success in this respect. At Niagara Falls all electrochemists naturally felt that they were at home, and much credit is due to the untiring efforts of the local entertainment committee. On the walks to the Falls, on the visits to the plants, on the trolley trip and the banquet many new acquaintances were formed; and no young electrochemist, who is proud to be an electrochemist, will ever forget the days when he could shake hands with such pioneers as Mr. Acheson, Mr. Bradley, Mr. Cowles and Mr. Hall. There was good will and good feeling all around, and we trust that it may always be so in the American Electrochemical Society.

## AMERICAN VERSUS GERMAN PRACTICE.

A certain conversation between two members of the American Electrochemical Society at the recent meeting at Niagara Falls was such a good illustration of one of the characteristic differences between American and German practice, that it seems worth while to call attention to it here, especially as we Americans are sometimes criticised rather severely by our foreign colleagues for doing things in a crude way.

While inspecting one of the interesting electrochemical processes, a member of German descent remarked, with great pride, that a certain German company, which had done this same thing fifteen years ago, had obtained a far greater percentage yield of the desired product; to which an American member replied, "and that is no doubt the very reason why the German company failed to make it a success, while the American inventor succeeded." With characteristic German thoroughness, the thing which seems to have been most prominent in the mind of the German experimenter was to get the greatest

possible percentage yield, and after he got the most he could he found that the process was too expensive. The American, however, attacked the problem in a more practical way; what he tried to get was at what percentage yield is the total cost of the desired ultimate product the least. This is certainly the proper way to consider a commercial proposition. In doing this he found that at a very poor yield the final product became quite cheap, while the German had blindly passed by this successful point in his efforts to get as near the theoretical perfection as possible.

As success is what most of us are, or should be, striving for, it seems to be more creditable to succeed in making practical and useful a theoretically-imperfect process, than to make it so perfect theoretically that it becomes useless, and a practical failure. The Germans may answer to this that it depends upon whether one is working for "glory" or for "money;" but is there not also "glory" in succeeding to develop something that is useful to the world at large? Is it not sometimes even greater than the credit of having developed a useless process to high theoretical perfection? We have great respect for the thorough, indefatigable work of the Germans, but we think that they are too apt to fail to appreciate that it also involves ability, patience and hard work to reduce things to practice.

Suppose the development of the electric light had been abandoned in its early days on the ground that it was theoretically extremely imperfect, having a light efficiency of only a few per cent.; we would, then, be still limited to gas and oil, as we were twenty-five years ago. There are other occasions like this in which wastefulness is economy.

Concerning the process above mentioned, it was very interesting and instructive to notice that in the experimental researches to determine the best values of each of a number of factors in the process, one of the co-ordinates in the curves of results was always the cost per pound of the ultimate product, or some similar factor. This, we think, is an eminently practical and the safest and most direct way of finding the best working conditions, and one which might well be followed by others who are searching for the lowest cost of production.

## ELECTROLYTIC PRODUCTION OF SODA WITH MERCURY CATHODES.

In the present issue we complete the presentation by abstract of the patented forms of electrolytic cells operating through the intermediary of a cathode of mercury to convert solutions of brine into caustic soda. Commercial success here, as always, has been a beacon which has attracted hosts of inventors, and here, as always, there is no single expression for the character of the inventions. The Patent Office is an indiscriminate collector, making no distinctions along the lines of relative value, but insisting only that there shall be no duplicates in its cabinet.

Through the wide diversity of forms there runs, however, a clear and almost vital distinction, the character and aspect of which seems to be little understood, even among workers in the field. This distinction hinges upon the quantity of energy represented by the decomposition, which is dependent upon whether or not the chemical energy of the oxidation of the sodium is transformed into electrical energy and turned into the electrolyzing circuit. If the oxidation of the alkali metal be effected by means of a "combining circuit"—in other words, if the mercury acts in whole or in part as a bipolar electrode between independent anodes and cathodes—the energy of this transformation is more or less conserved. If, on the other hand, dependence is placed on local action or area of contact for insuring a rapid denudation of the amalgam, the voltage theoretically required for the decomposition is considerably increased. If the surface at which the oxidation of the sodium occurs is not an active electrode face, it becomes immaterial, electrically, what separation, in space or time, may exist between the act of forming the amalgam and its decomposition by water.

## THE ST. LOUIS WORLD'S FAIR OF 1904.

The Electrical Department of the St. Louis World's Fair has a very energetic director in Professor Goldsborough. At the Niagara meeting of the American Electrochemical Society he made a strong appeal to the electrochemical manufacturers, and, we hope, it will have the desired effect. It is high time to show before the country and before the world the advances of American electrochemical industries. It is sometimes astonishing to find how little the general public knows of electrochemistry and electrometallurgy. Everybody knows aluminum, but very few know how it is made; in fact, the general public is absolutely ignorant of the nature of electrochemical processes. These conditions should certainly be changed in view of the fact that the value of the output of the electrochemical industries in the United States is at present estimated at about $100,000,000 per year.

The general public cannot be blamed for its ignorance. People have never had an opportunity to see electrochemical processes in operation; of course, they all know and use products of electrochemical industries, but while seeing and using the finished product, they do not know anything about the method by which it is made. Even the finest display of finished products of electrochemical and electrometallurgical industries would not teach the general public anything concerning the methods and possibilities of electrochemistry. To interest people in electrochemistry, it is necessary to show them by an object lesson how electrochemical processes are being worked. Director Goldsborough hits the point in urging manufacturers to exhibit model plants and to show processes in operation.

Director Goldsborough also meets at once a difficulty which seems to be in the way of the fulfillment of his plans. It is a fact that electrochemical manufacturers generally do not want to say or show anything about their methods. Professor Goldsborough points out correctly that manufacturers are not expected to show their trade secrets before the public. What they are urged to show are the general principles of their processes in operation—even if the details of working in the model plant exhibited differ greatly from the methods employed in the industrial plant. If the general public can thus be educated in the general nature and the unlimited possibilities of electrochemical and electrometallurgical processes, an advance of industrial electrochemistry is bound to follow, in comparison with which the progress made in the last ten years may appear slow.

## THE EFFICIENCY OF ELECTRIC FURNACES.

In the following we give an abstract of the recent American Electrochemical Society paper by Dr. J. W. Richards on this subject:

An electric furnace is a furnace for accomplishing a physical or chemical change in materials by means of the agency of heat, said heat being supplied by the transformation of electrical energy. The cases where electrolysis take place in fused electrolytes, are left out of consideration, because they are essentially electrolytic processes in which the heating of the current is unavoidable and incidental to the main process of electrolysis and must be excluded from the term "electric furnace processes," if that term is to retain its individuality and stand for a definite class of operations. If this limitation is understood, the output of an electric furnace is more or less proportional to the amount of heat energy developed in the furnace. It is necessary to say "*more* or *less* proportional," because, although the amount of heat necessary to produce the change in a given amount of material may be a perfectly definite quantity, yet the proportion of the heat developed in the furnace which is actually absorbed or applied in producing this change is a variable one, being always less than 100 per cent., and frequently very much less. The proportion of the heat energy of the electric current thus applied to producing the useful change in the charge is called the *efficiency* of the furnace.

The usefully applied heat will include one or both of two factors. The first is the amount of heat necessary to heat the charge up to the temperature of the furnace. The second is the heat absorbed in chemical reactions between the constituents of the charge when they are heated to the reacting point. This second part of heat can be calculated from thermochemical data, while the former part of heat—that required for the purely physical changes—can be calculated from the mass of the charge, the specific heats in the solid and liquid states, the latent heat of fusion and the temperature of the furnace.

The efficiency of an electric furnace operation depends on many factors, among which are the following: size of furnace, temperature of reaction, protection from radiation, management of the terminals, feeding and tapping, general management. Of these the most important, in commercial practice, is the size of the furnace. The volume or contents of a furnace increase approximately as the cube of the linear dimensions, while the radiating surface which conditions the loss of heat, increases as the square of the linear dimensions; therefore the proportion of radiating surface to unit of contents *decreases* approximately in proportion as the linear dimensions are increased. It is probable that if a 100 horse-power electric furnace works at an efficiency of 50 per cent., with the other 50 per cent. lost by radiation and conduction, then an 800 horse-power furnace of the same design, working the same process at the same temperature, should give an efficiency nearer to 75 per cent. Most of the desiderata of commercial success of electric furnace work lie in the direction of increasing the size of the furnaces to the furthest limit set by mechanical or physical considerations.

While electric furnaces are generally classified into the resistance type and the arc type, it is better for the present purpose of calculating the efficiency to use a different classification. All furnaces are divided into two large classes. The first class includes those furnaces in which the charge is simply heated without any *chemical* change taking place; the second class includes those in which besides the heating of the charge there is also a chemical change. Each class may be again subdivided into two subclasses, according to whether the heating takes place with or without a melting or fusion of the charge.

*Heating with at Fusion and without Chemical Change.*—An example of this is the conversion of anthracite coal into graphite in the Acheson furnace. It is true that some chemical changes probably occur during the conversion, such as the progressive formation and decomposition of carbides, but these are negligible because their plus and minus heat quantities neutralize each other; the change from amorphous carbon to graphite is a heat *evolving* reaction and therefore must be reckoned as really *assisting* the current or, practically, diminishing in our figuring the calculated efficiency. The data are as follows: 1,000 horse-power, in twenty hours, convert 12,000 pounds of anthracite into 10,000 pounds of graphite. The heat gained in conversion into graphite is about 10 per cent. of the heat supplied by the current; hence the real amount of heat is 110 per cent. of the heating power of the current; of this 82.5 per cent. are utilized, giving an efficiency of $82.5 \div 110 = 75$ per cent. In the Acheson process of graphitizing electrodes by placing them crosswise, embedded in a resistant material, 1,000 porse-power graphitize 7,000 pounds of electrodes, embedded in 7,000 pounds of granular carbon and lining; the net efficiency of the operation is 38 per cent.

*Heating with Fusion, but without Chemical Change.*—The Jacobs process of fusing calcined bauxite is an illustration. The process is simple fusion by the arc, in a cylindrical pot. With a charge of 3,000 pounds the efficiency is 74 per cent.

*Heating without Fusion, but with a Chemical Change.*—The manufacture of carborundum is a good example. A mixture of carbon, silica sand and salt is heated by the incandescence of a conducting carbon core, until the salt is volatilized carrying off most of the metallic impurities as chlorides, the silica is reduced and combines with the excess of carbon present to form silicon carbide. The furnace is 20 feet long, and 1,000 horse-power is passed through for thirty-six hours. The calculation of the efficiency gives 76.5 per cent.

*Heating with Fusion and with a Chemical Change.*—An example is the production of calcium carbide, for which the calculation gives a net efficiency of 62 per cent. There is, however, a distinct experimental gap in the lack of knowledge of the specific heat of such products of the electric furnace, at high temperatures. When these are known, calculations of the efficiency can be made with much greater exactness.

The net result seems to point to a commercial efficiency of 60 to 75 per cent., calculating with furnaces of 200 to 1,000 horse-power. It seems that furnace operations which involve a heating effect only, without any chemical change, give a higher efficiency in general than those in which a chemical change is also involved. The value of such approximate figures is that any one starting an electric furnace operation should be able to calculate the approximate output to be expected, or, if planning or designing for a given output, will have a guide to indicate the approximate size and capacity of the furnaces needed.

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## CATHODIC REDUCTION.

In his American Electrochemical Society paper on this subject, Alfred T. Weightman, of the Electrical Lead Reduction Co. of Niagara Falls, brought out several points which are interesting from a theoretical point of view, and at the same time of practical importance for the electrochemical engineer.

The result of the electrochemical action at a cathode is always reduction—either of ions in the solution, or of the electrode itself. In the first case, that of the reduction of ions, the problem becomes complicated if there are several kinds of cations in the solution which can be reduced; *i. e.*, if we have a mixture of several electrolytes, for instance $ZnCl_2$ and $Cu\,Cl_2$. Both the Zn and Cu ions are active in transporting the current through the solution; but this does not mean that both must be reduced or deposited upon the cathode. The principal factor which determines the kind of ion to be deposited is, of course, the heat of formation of the different possible reactions: that reaction which absorbs the least energy occurs, in general, most readily; but this statement is only approximately true. The concentration of the two electrolytes and the current density must also be taken into account.

In the second case, that of the reduction of the cathode itself, the cathode is usually a compound of a metal, and the cations (usually H ions) combine with the non-metallic radicle forming a new compound. The best known example is the reduction of the negative plate of a storage cell during charge, from lead sulphate to metallic lead. In this case the cathode consists partly of sulphate and partly of metallic lead (the grid or active material which has already been reduced); hence the two following reactions are theoretically possible: first, the evolution of hydrogen at the metallic lead; second, the reduction of sulphate to lead. From the thermochemical data it appears that the reduction of the sulphate requires a slightly higher voltage than the liberation of hydrogen. It is, therefore, astonishing that not more hydrogen is evolved from a negative plate during charge than is actually found to be the case.

In the Salom process of the electrolytic reduction of galena to metallic lead the reactions are similar. PbS is reduced to Pb, and $H_2S$ is formed. But on considering the heat of formation of the two possible reactions (evolution of hydrogen or reduction of galena), they are found to lie even farther apart than in the case of the reduction of lead sulphate in the storage battery. The author has made a very large number of experiments with a view to producing as small an evolution of hydrogen as possible, or, in other words, raising the current efficiency as high as possible, so as to reduce the largest quantity of galena for a given current. The author has found that the efficiency is extremely sensitive to the degree of purity of the ore and the nature of these impurities; to the conductivity of the ore; to the fineness of grinding; to the strength and purity of the electrolyte; to the thickness of the layers of ore; to the temperature of the solution, and various other causes—but strange to say, it is almost unaffected by the current density used. The author exhibited several curves and tables, showing the results obtained with various current densities; the similarity in the shape of the curves under different current densities is remarkable; in fact, the numbers of amp. hours required for a given percentage of sponge in the ore agree within the limits of experimental error.

As noticed above, the reaction $PbS + H_2 = Pb + H_2S$ requires a very much higher absorption of energy than the mere liberation of hydrogen; and yet, under proper conditions, the former reaction, which is the one that is wanted, can be kept up to an efficiency yield of 80 per cent., or over, for two-thirds of the reduction, even when the galena is present to the extent of only 25 per cent. On the other hand, it is all the more disappointing that the reaction cannot be brought to a completion, as the last 5 per cent. of PbS cannot be reduced. This, of course, necessitates further treatment to obtain a pure product.

The author has also made experiments concerning the reduction of other sulphides. He used $Cu_2S$ and NiS; the results obtained are quite different from those for PbS.

For the explanation of the phenomena, the author refers to Caspari's theory of the overvoltage (Ueberspannung). According to this there is a certain overvoltage required to evolve hydrogen, and this overvoltage is different for different materials of the cathode. This overvoltage may account for the results, unexpected from the thermochemical data.

## STORAGE-BATTERY INVENTION.

In an American Electrochemical Society paper on this subject, Hugh Rodman discussed the prospects of the Edison battery in comparison with the lead cell.

The author first discussed some general requirements which must be fulfilled in a commercial battery, and which greatly limit the number of possible combinations. A commercial cell must be able to stand an overcharge; and when it is being overcharged, there should be unchanging electrodes in an unchanging electrolyte; the author shows that this requirement reduces the list of available anodes and electrolytes to lead in sulphuric acid and nickel in alkali hydroxide. This does not mean, however, that the active material must necessarily contain nickel or lead, but simply that the grid must be one or the other of these metals in its appropriate solution. If permanency only is considered, the active material of the "oxygen plate" may be any insoluble oxide or salt; while the grid and active material of the "hydrogen plate," putting aside as impracticable any dissolving material such as zinc, may be either of the same metal as the oxygen plate, as lead in sulphuric acid, or else of some other metal soluble only at the end of a complete reversal of current, as iron in hydroxides. Practically, the whole problem is thus reduced to two classes: first, lead peroxide and spongy lead upon lead plates in sulphuric acid, *i. e.*, the common lead cell; second, mercuric or nickel peroxide upon nickel plates, together with cadmium, nickel or iron sponge upon iron or nickel plates in an alkali hydroxide, *i. e.*, the Edison battery. As the most promising example of the latter type he considers the Edison nickel iron cell and compares it with the ordinary lead cell, concerning the grid, the active material, the electrolyte, and in general.

Concerning the grid the author remarks that the alkali battery has the great advantage of having its support plates of a stiff, easily-worked metal.

Concerning the active material he points out that lead peroxide is a conductor, while nickel peroxide is not, and so must be held in close contact with some conductor itself inactive, as nickel or carbon. Edison packs the active material with powdered or flake graphite, held rigidly in a perforated box. An objection to this is that the dense active mass impedes diffusion. An advantage is that the close-held mass, with its stiff, finely-perforated cover, is apparently not subject to deterioration.

Concerning the electrolyte there is a great difference between the two types of cells. In the acid battery a mass of electrolyte is required, large enough to hold both the acid needed for the reactions and enough over to insure low electrolytic resistance at the end of the discharge; in the alkali battery only enough electrolyte is required to make a bath for the current. While this is one of the most important factors in making the alkali cell light, it adds greatly to an already serious trouble: refilling. Here the alkali cell is inferior to the lead cell. First, the overcharge is greater, on account of the more difficult diffusion. Second, the current is greater for the same energy output. Third, the alkali cell has comparatively a small mass of electrolyte to draw upon. The author thinks that in all, the question of the mass of electrolyte comes to this: that "in the alkali battery we multiply a serious trouble by a factor of three or four, and then halve the means of getting around it." Another trouble arising from refilling is the quality of water used in practice. If the hydrant is the source of supply, it may be the means of putting into the electrolyte some active agent that eventually disintegrates the plates. Again, the acid electrolyte is commercially the better for the ease of handling. Finally, the author thinks, that a battery with unchanging electrodes and changing electrolyte would, in many ways, be better than its opposite; for instance, the change of electrolyte density is, in the lead cell, a very useful means of determining the state of charge and discharge.

Concerning the uses of the storage battery, the author believes that for central station work, which at present takes about 75 per cent. of the battery output, the position of the lead cell seems secure, while for lighter service, particularly for automobiles, where watt efficiency and cost are to some extent subordinate to convenience, the choice will depend largely upon capacity and reliability. Exact data on the alkali cell are wanting and must be wanting until the cells are put into ordinary service with ordinary care and attention; it seems certain that the necessity for frequent refilling will mean trouble and irregularity of working, while the problem of handling the alkali electrolyte and excessive gasing will need most careful consideration.

The author states that the commercial life of lead plates in truck or cab service is about 15,000 to 20,000 miles for negatives, 12,000 miles for Plante positives, and 6,000 miles for pasted positives. In other words, a 4 or 5 ton truck running 20 miles per day for 300 days in a year requires new positive plates once in a year, or once in two years, according to the type of plate used. Cabs and lighter wagons have about the same life with a capacity of 40 to 100 miles on one charge. Under these conditions experience has shown that the electric wagon gives better city service than can be gotten from gas or steam or horse. If a better battery than the lead cell was available on the market—either an improved lead cell or a better new one—it would control practically all city traffic not on rails.

## ELECTROLYTIC DISSOLUTION OF SOLUBLE ANODES.

In a paper read before the American Electrochemical Society, Woolsey McA. Johnson made an attempt to co-ordinate the different factors which are of influence in the electrolytic dissolution of soluble anodes consisting of an alloy of different metals. In some respects his problem is the anodic analogon to the problem of cathodic reduction, dealt with by A. T. Weightman.

The fundamental facts upon which Mr. Johnson bases his theoretical considerations, are as follows: Every metal has a certain specific "electrolytic tension," or potential difference against an electrolyte, this potential difference depending on the nature of the electrolyte and the general physical conditions. Every metal has a specific electrical conductivity. These two properties—potential difference and conductivity—are profoundly modified by alloying with other metals. On these resulting properties of alloys segregated in the anode, depends the selective electrochemical dissolution of the anode.

In most cases alloys are formed with the evolution of heat; the resultant product is harder and has less tendency to dissolve. Further—and this is of greater importance—with the exception of several metals as zinc and cadmium, two metals unite to form an alloy the electric conductivity of which is smaller than that of either.

If, for instance, a particle of silver-copper alloy is considered which is surrounded by pure copper crystals; as the alloy has a much lower conductivity, it is to be expected that the current is shunted around the silver-copper alloy and finally dissolves its copper backing; it then can be brushed off into the "slime." On the other hand, if a "bi-metallic" anode is used, *i. e.*, a sheet of copper, by the side of which is a sheet of silver one two-hundredth of the size, it will be found that the silver dissolves at a much lower current density than in the case of the alloyed anode. The only difference in both cases is that in the first the silver is alloyed with the copper and not in the second.

Arsenic and antimony, if present as metals besides copper, would have a greater tendency to dissolve than copper, on account of their high electrolytic solution tension. But, in practice, for the same reasons which were just explained, they pass into the slime directly from oxidized anodes.

The author believes that much can be saved in copper refining by previous treatment of the anodes. A careful metallographical examination of the anode and some little thought on the alloys that can be formed, will reduce any electrorefining proposition to its simplest terms.

## ON THE THEORY OF THE ELECTROLYTIC RECTIFIER.*

By Prof. K. E. Guthe.

An explanation of the peculiar phenomenon that an aluminum plate immersed in an alum solution will allow a large current to pass in one direction, but only a very small one in the other, may be attempted from two different points of view. First, we may assume that the current, when the aluminum plate forms the anode, produces a non-conducting film *i. e.*, introduces an ohmic resistance, while this film breaks down with the current flowing in the opposite direction. Moreover its resistance must vary with the current strength, because it decreases apparently as the current towards the aluminum increases, *i. e.*, we have here an exact analogy to the so-called "resistance of transition," formerly supposed to exist in ordinary electrolytic cells.

The other point of view starts with the assumption of a very high electrolytic polarization (25 to 30 volts). According to this the ions are prevented by some cause, whatever it may be, from reaching the electrode and from giving up their electrical charges, unless they have obtained a certain amount of energy enabling them to overcome the obstacle. In favor of this latter conception—though the two do not necessarily contradict each other—may be mentioned, that a decrease in the size of the plate does not appreciably alter the current as we should expect, if the resistance were ohmic in its character.

So far the whitish, non-conducting oxide or hydroxide film on the plate has been held responsible for the formation of this high apparent resistance. But since no change can be found in the film under different conditions, and, since the resistance returns with remarkable regularity to the same value for the same current, the author considered the assumption of the formation and subsequent breaking down of the film as improbable.

He brought the plate, on which a high resistance had been produced, into a vacuum and found that a large number of minute gas bubbles appeared at the plate, showing the presence of a gaseous film. Removing this, at least partially, under the air pump, the resistance of the plate was greatly reduced.

The explanation given for the behavior of the aluminum rectifier is, then, that with the aluminum as anode the oxygen gas formed is kept in the meshes of the solid oxide film and thus prevents the passing of the ions, until by increasing the potential difference at the terminals of the cell, the energy of the ions is raised sufficiently to break through the gaseous film. On the other hand, the hydrogen produced by the current when flowing in the opposite direction is not held back in the solid network, but escapes freely. Consequently, we have no high resistance when the aluminum plate forms the cathode.

Some experiments were undertaken to prove the conclusions to be drawn from this theory. Increase of temperature decreases the apparent resistance. The concentration of the electrolyte does not influence the phenomenon. Different electrolytes depositing oxygen at the plate—solutions of alum, rochelle salt, ferrocyanide of potassium, copper sulphate and zinc sulphate—show all the same behavior. Anions, as chlorine, will not produce the high resistance, since they act in the same manner as hydrogen.

Since we have here a kind of a semi-permeable membrane, the author has examined the well-known membrane of copper ferrocyanide, deposited in a porous cup, and found it to act qualitatively the same way as the aluminum plate. In a cell, formed by copper, solution of copper sulphate, membrane, ferrocyanide of potassium solution, platinum—only a small current could be obtained in the direction from the copper to the platinum, the counter e. m. f. of polarization rising as high as 20 volts, while the current would pass unobstructed in the opposite direction. A film deposited on a copper plate immersed directly in a solution of potassium ferrocyanide behaved in the same way.

In conclusion, it was pointed out that this theory might be able to explain ordinary polarization by the assumption of a liquid high-resistance film—possibly pure water—between the electrodes and the electrolyte; an explanation which would also facilitate our understanding of the peculiar fact, that hydrogen polarization appears to have very different values accordingly as it is deposited on platinum, lead or mercury.

*Abstract of a paper read before the A. A. A. S. at the Pittsburg meeting, July, 1902.

# NIAGARA AS AN ELECTROCHEMICAL CENTRE.

## THE ELECTROCHEMICAL INDUSTRIES OF NIAGARA FALLS.

By Joseph W. Richards, Ph.D.

*President of the American Electrochemical Society*

*(Concluded)*

### The Pittsburg Reduction Co.

THIS company were organized in 1888, by the late Capt. A. E. Hunt, to work the Hall process of producing aluminum. The chief investors were the Mellon Bank of Pittsburg and Messrs. Hunt and Clapp, of the Pittsburg Testing Laboratory. At present, R. B. Mellon, of Pittsburg, is president; Charles M. Hall and G. H. Clapp, vice-presidents; Arthur V. Davis, secretary and general manager. Originally, $20,000 was subscribed to start the company, but at present the capitalization of the company is $600,000 of 6 per cent. preferred stock and $1,000,000 ordinary stock, paying 8 per cent Mr. Hall lives at Niagara and has charge of the operation of the Niagara works.

There are two plants of this company at Niagara: the upper plant, situated on the grounds of the Niagara Falls Power Co.,

UPPER WORKS, PITTSBURG REDUCTION CO.

above the falls, and using 4,000 horse-power; the lower, situated on the edge of the gorge below the falls, and taking 6,500 horse-power from the Hydraulic Power and Mfg. Co.

The upper plant is situated half a mile above the upper power house, on a 10-acre plot of ground, and was the first plant to utilize this upper power. When, in 1893, the Niagara Falls Power Co. completed their power house, the next step of finding customers for the power was not easily solved, and special inducements were made to the Pittsburg Reduction Co. to break the ice and become the first plant to utilize this power. The offer took the shape of a contract to furnish the direct current needed for the process, at a certain price per horse-power per year, which price is a private matter between the two companies, but is understood to be not over $18 per horse-power-year. This necessitated the installation by the power company of transformer machinery, at the reduction plant, which is owned and operated by the power company. This is, as far as is known to the writer, the only case in which this power company have furnished the current transformed to suit the customer's purpose, all subsequent contracts being at $18 to $20 per horse-power per year for the alternating current at 2,250 volts, the purchasers putting in and operating their own transformer machinery.

The alternating current is first passed through a set of twelve air-cooled stationary transformers, which reduce its potential to 115 volts and raise its ampérage correspondingly, with a loss in conversion of 3 per cent. It then passes to rotary transformers, of which there are six each of 800 horse-power, which transform the alternating current of 115 volts into direct current at 160 volts, with another loss of 3 per cent. in conversion. Five of these, run to full capacity, furnish two currents of approximately 10,000 ampères by 160 volts each; sometimes all six are run, at five-sixths full capacity, to furnish the same current.

Each current passes through a line of reducing pots, being conducted on aluminum bars, 12 inches by 1 inch, giving a carrying capacity of over 800 ampères per square inch of conductor. The bars are not insulated, the low voltage rendering that unnecessary. The voltage drop at each pot is a little over 5 volts, each pot absorbing about 65 horse-power. The current passes into each pot through carbon electrodes, 3 inches diameter by 18 inches long, each carrying 250 ampères of current. It is found that this is about the maximum current which can be carried by the copper-rod connections without undue overheating. About one-half the energy of the current is absorbed in the chemical work of decomposing alumina, the other half is converted into heat and keeps the bath at the proper temperature and fluidity necessary for electrolysis—about 850° to 900° Centigrade. The efficiency of recovery reckoned on the ampères used is between 80 and 90 per cent. The bath is the ordinary Hall bath, containing cryolite, to which is added aluminum fluoride, as the solvent, and with alumina dissolved therein. The action of the current sets free aluminum and oxygen, the latter uniting with the carbon anodes to carbonic oxide. Although 4,000 horse-power are being used, the smell of fluorine is usually not perceptible in the pot room, except during casting or trimming up a pot. The aluminum obtained averages 0.1 per cent. iron, 0.3 per cent. silicon, with smaller amounts of copper, titanium, carbon and sodium, but is guaranteed over 99 per cent. pure, averaging more nearly 99.5 per cent. The selling price of such metal is, in ton lots, 31 cents per pound; less pure metal is made from less pure alumina, and sold, for use in casting iron and steel, at 2 cents per pound less.

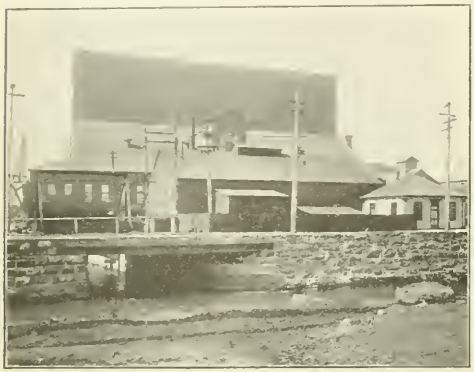
The main reduction room is an iron building, 180 by 85 feet, with a high roof. The windows are whitened by the hydrofluoric fumes occasionally escaping, but the fumes in the building are seldom strong enough to be perceptible. The metal is run into rough ingots, weighing 20 pounds each, and the total output from this plant must be in the neighborhood of 7,200 pounds daily. The crude ingots are shipped to New Kensington, Pa., to be remelted and converted into commercial shapes.

Alongside this main room is a building of equal area, but not so high, in which are kept the stock of metal, and also stocks of alumina and carbons. It contains furnaces for baking the carbon lining in the pots, and machinery for drilling and repairing the carbon electrodes. There is also a well equipped laboratory, presided over by Wm. T. Whitten, with several assistants.

The company own large deposits of bauxite, the native hydrous aluminum oxide, in Georgia and Alabama.

In 1900 Mr. Hall invented an entirely new method of commercially purifying alumina (U. S. Patents 677,207, 677,208, 677,209, of June 25, 1901), which will receive its first commercial application at Niagara Falls. The bauxite is mixed with sufficient reducing agent, such as carbon, to reduce all the impurities in it to the metallic state, *i. e.*, silica to silicon,

titanic oxide to titanium, iron oxide to iron. The mixture is then melted up in electric furnaces, using a carbon pole, the material itself being fed into the arc and the melted alumina constituting the other pole. An alternating current of low voltage is used. The impurities collect as a metallic alloy of iron, aluminum and silicon, while the purified alumina above is almost chemically pure. The furnace is let cool and the contents separated when cold. It is estimated that in this way the bauxite can be purified at less cost than by the wet, chemical processes. The alumina produced is granular, heavy, dissolves well in the pots and produces a metal of high purity.



LOWER WORKS, PITTSBURG REDUCTION CO.

The lower plant of the Pittsburg Reduction Co. is situated on the edge of the gorge, one-quarter mile below the steel bridge, and immediately above the power house of the Hydraulic Power and Mfg. Co. The current is generated in the power house, as direct current, by means of Westinghouse dynamos of 750 horse power each, coupled direct to turbines with horizontal shafts, the current being conveyed on aluminum cables, of 28 square inches sectional area, a distance of 250

THE CARBORUNDUM CO.

feet to the reduction room on the bank. Each dynamo gives a direct current of 2,000 amperes, at a potential of 280 volts, and nine such machines furnish the 6,500 horse-power necessary to run three lines of pots (2 lines are run at the upper works by 4,000 horse-power). The method of reduction is exactly the same as at the upper plant, and the output approximately 50 per cent. greater, making the total output of both plants probably 19,000 pounds per day. The building has its roof extended into an enormous ventilator, giving it the appearance of a grain elevator, but this greatly increases the comfort of the workmen. No other work than reduction is performed here, for which a force of about 150 men, working in eight-hour shifts, suffices. At the upper works the force is about 200.

Besides these works this company have recently extended their plant by the installation of 5,000 horse-power at Shawinigan Falls, Quebec, and the acquisition of 12,000 horse-power and 100 acres of ground at Massena, N. Y., on which an aluminum plant will be erected. Our congratulations to the enterprising pioneers of the aluminum industry in America!

### The Carborundum Co.

This company also owe their organization to Pittsburg capitalists, who in 1893 organized them to work the processes of A. G. Acheson for producing carborundum. The present officers are: F. W. Haskell, president; F. J. Tone, works superintendent, and among the larger stockholders are A. W. and R. B. Mellon, Pittsburg; A. G. Acheson and G. R. Rayner, Niagara Falls.

Carborundum is carbon silicide, CSi, and is formed by intensely heating, in an electric furnace, a mixture of carbon, sand and salt. Mr. Acheson first made it while trying to melt

A CARBORUNDUM FURNACE.

carbon and clay together, and to crystallize out the carbon, and obtaining some bright blue crystals in this manner, which were certainly not pure carbon, he suspected that they were a compound of carbon and alumina, and constructed for them the name *carborundum*. Analysis, however, showed these crystals to contain 60 per cent. of silicon, 30 per cent. of carbon and only 4.78 per cent. of alumina. Experiments then followed with mixtures of carbon, silica sand and salt as a flux, and large crystalline masses of the new product were obtained. Its hardness suggested its use as an abrasive, since it is nearly as hard as the diamond, and its commercial manufacture as a substitute for emery and corundum soon followed.

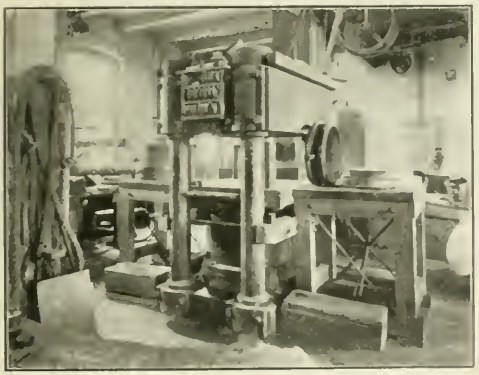
The furnaces employed at Niagara Falls are horizontal, and take 1,000 horse-power each. There are two blocks of five furnaces each, of which one furnace in each block is in operation, while the other four are either cooling off, being emptied

or being loaded up for a fresh run. The bed of fire brick is 16 feet long, 5 feet wide and stands 2 feet above the floor. The ends are of solid brickwork, 2 feet thick and 8 feet high, in the center of which are square iron frames, in which are drilled holes. Through these holes the strands of the conducting copper wires pass, and are connected to the terminal carbons, bunched together, which lead the current into the furnace. Directly in contact with these carbons is placed the conducting carbon core, which conducts the current through the furnace

CARBORUNDUM.

and by its resistance raises the temperature sufficiently to reduce the carborundum-making mixture which surrounds it. When charging is completed, the carbon core is surrounded on all sides by the mixture to a distance of 2 to 3 feet, and the top is rounded off like a mound. The electrical connections are now made to the iron frames, at the extreme ends of the furnace, and the charge is ready to burn.

The alternating current of 250 volts is passed into a 830 kilo-watt (1,100 horse-power) stationary transformer, which



A CARBORUNDUM PRESS.

cuts its voltage down to an average of 185 volts. A regulator allows the current to vary from 100 volts up to 250, while the ampères vary from 2,000 up to 8,000. The 4 per cent. loss in transformation, representing 40 horse-power, would heat up the transformer, but is counteracted by cooling it by circulating currents of oil.

The furnace starts at high voltage and low amperage, because of the poor conductivity of the carbon core when cold. The total contents of the furnace are about 1,000 pounds of carbon core, and the mixture reduced represents 3.5 tons of carbon mixed with 6 tons of silica sand and 1.5 tons of salt, producing in a thirty-six hour run between 3 and 4 tons of commercial carborundum, in crystals, outside of which is a quantity of light-green amorphous carborundum, fully reduced, but uncrystallized, and outside of this the unchanged mixture. Near the carbon core, where the heating is most intense, are found some crystals of carborundum from which the intense heat has volatilized the silicon, leaving a skeleton crystal of graphite, while the silicon, passing outward as vapor, oxidizes to spongy, felt-like silica as soon as it meets carbonic oxide gas. Some of the vapor has been found condensed to metallic silicon in cracks in the bed of the furnace. The observation of the formation of graphite by the very evident decomposition of the silicon carbide, was the starting point of the graphite industry now conducted by Mr. Acheson in an adjacent plant.

A third block of furnaces is now in course of construction, which will raise the power requirement to 3,000 horse-power,

A CARBORUNDUM KILN.

and increase the output of carborundum to 1,800 tons per annum.

The furnace after a run, is allowed to cool several hours, then gradually uncovered, the unreduced mixture removed, the reduced, but uncrystallized, carborundum is put aside to be mixed with another charge, and five to fifteen inches of well-crystallized carborundum next to the heating core is carefully gathered up. The carbon core serves only as a heating agent; very little of the current during reduction passes through the mixed carbon mixture, which is in reality a very poor conductor of electricity. The process is, therefore, simply that of heating the mixture to be reduced by the heat generated in a carbon conductor, which carries the current and which is surrounded by the mixture. The electric current not only heats up the immense mass of charge, but also supplies the heat absorbed in the chemical reactions involved. A consideration of the power used and the products obtained in one run, leads to the conclusion that about 25 per cent. of the energy of the current is needed to heat the materials up to the

reaching temperature, 50 per cent. in supplying the great quantity of heat absorbed in the chemical process of reduction and only some 25 per cent. is lost by radiation during the run (the 25 per cent. first spoken of is lost by radiation after the run has ended).

The cost of power alone amounts to 1.25 cents per pound of crystals obtained, the cost of materials for the mixture 0.75 cent and labor probably another 0.5 cent, making the estimated cost of crude crystals 2.5 cents per pound. This material must be otherwise treated before being ready for market. This subsequent treatment consists in crushing the masses to coarse powder, allowing this to stand several days in dilute sulphuric acid, to remove any such impurities as iron oxide, then washing and grading. The final cost of the powder or grains may be 4 to 5 cents per pound. It is sold at an average of 9 cents per pound; the manufacture of 2,400,000 pounds yearly providing, therefore, an estimated profit of $100,000 to the company. A large part of the product is, however, worked up by the company themselves into wheels, hones, etc., of all sizes and descriptions, the manufacture of which occupies, with its presses, baking ovens, kilns and stock rooms, the greater part of the floor space in the company's factory. This manufacture is an additional and large source of profit.

The crystals are graded in 20 sizes, from No. 8, passing

INTERNATIONAL ACHESON GRAPHITE CO.

through 8 meshes to the linear inch, to No. 220, passing through 220 meshes to the linear inch. The washings from the finest crystals pass into settling tanks, producing so-called *carborundum flour* of three grades of fineness, F, FF and FFF. The finest powders are made by stirring fine powder or flour in water, letting it settle a definite time, one, four, six, ten or fifteen minutes, decanting the liquid and then settling the powder from this by long standing. Such powders are called *hand-washed* one, four, etc., minute powders.

The factory buildings are two and three stories high, covering three sides of a four-acre plot of ground, and contain 120,000 feet of floor space. They contain costly machinery, presses, drills, etc., for making the carborundum up into wheels, sticks, hones, sharpening stones, cloth, paper, etc. The greater part of these goods are made up with a bond of kaolin and feld-spar, which becomes vitrified in the subsequent kiln burning, producing the firmest "body" which can be made.

A particular use to which carborundum has been put is the addition to steel, to secure sound castings, it being thus possible to introduce silicon without bringing a trace of phosphorus or sulphur into the steel. Since the carborundum contains 70 per cent. of silicon to 30 per cent. of carbon, it is very efficient for this purpose.

Immediately in front of the factory is the new office, built in colonial style after designs of Mr. Haskell, president of the company, and one of the prettiest office buildings in Niagara.

### The International Acheson Graphite Co.

Manufactured graphite was suggested as a commercial possibility to Mr. Acheson by finding in the center of his carborundum furnaces masses of graphite resulting from the overheating of carborundum. The making of carborundum is a delicate operation, the proper adjustment of current to core being absolutely necessary for producing a good output. It has been stated that an increase of 3 per cent. in the size of the conducting core, in a carborundum furnace will result in a great decrease in the amount of carborundum formed, because of deficient temperature, while an increase of 3 per cent. above the normal will result in the conversion of considerable carborundum into graphite, by volatilization of its silicon. In other words, the temperatures of formation and of decomposition of carborundum lie somewhat close together, probably not over 500° Centigrade apart.

Having thus an idea of a new principle which was available for producing graphite, Mr. Acheson experimented further, with the result of becoming convinced that all metallic carbides, on being decomposed by heat, leave behind graphite, and his patents and process are based upon that fact.

The company concerned was organized in 1899, with Mr. Acheson, president; A. W. Mellon, Pittsburg, vice-president, and P. McN. Bennie, secretary. The patents by which they work are U. S. Patent 542,982, of July 23, 1895, which relates to the production of pure electric-light carbon by subjecting impure carbon to a high temperature for a sufficient length of time to volatilize its impurities; U. S. Patent 568,323, of September 29, 1896, and 617,979, of January 17, 1899, which disclose the principle of converting carbon into graphite by mixing it with such metallic oxides as would be capable of forming metallic carbides, to be subsequently decomposed; U. S. Patent 645,285, of March 13, 1900, which claims the use for conversion into graphite of such natural carbonaceous materials as contain uniformly intermixed through them metallic oxides sufficient to produce carbides and thence graphite. These patents, taken together, not only form the basis of the commercial manufacture of graphite, but throw much light on the scientific question as to the manner of its formation.

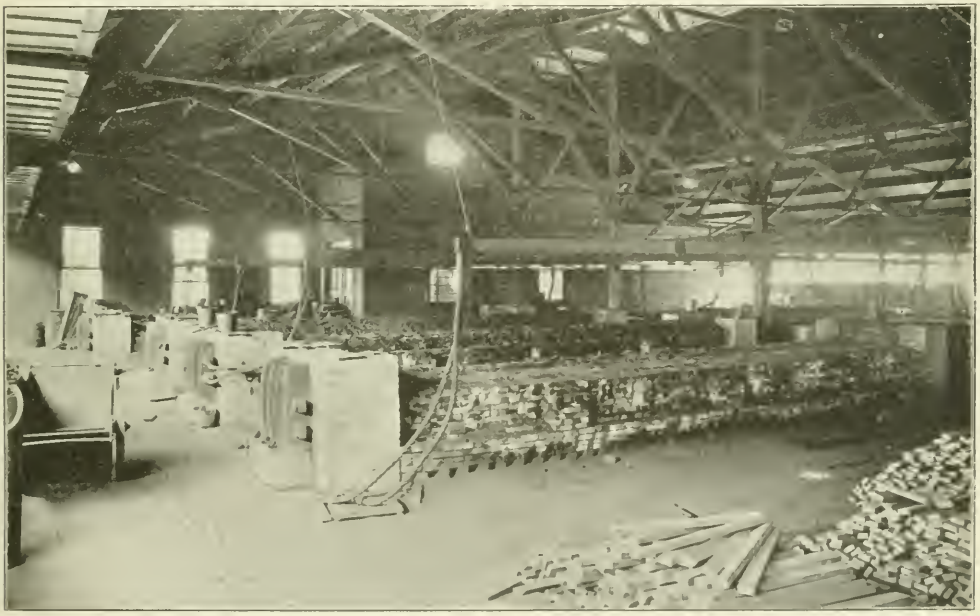
The furnace building is of brick and iron, 100 x 50 feet, and contains two rows of five furnaces each. Back of this is a frame building with machinery for grinding coke and coal, and making the furnace mixtures. The power used is 1,000 horse-power, converted down from 2,250 volts to an average of 150. The blocks are run very much like carborundum furnaces, in that while one furnace is being run, the four others are in various stages of dismantlement or re-filling. The commercial work of the company has resolved itself into two lines of manufacture: (1) the graphitization of molded carbons, (2) the graphitization of anthracite coal *en masse*. The product is, in either case, pure graphite, which should be known as *manufactured* graphite rather than *artificial* graphite, since it is no counterfeit of graphite, but the real graphitic carbon itself. A good summary of the history of the invention, by Mr. Acheson himself, may be found in the *Journal of the Franklin Institute*, for June, 1899, and a discussion of the value of the resulting product, by Mr. Collins, in the *Transactions of the American Electrochemical Society*, Vol. I, 1902.

The conversion of molded carbon articles into graphite is performed by stacking them transversely to the current in a pile about 2 feet square, between terminals 30 feet apart, and covering them thickly with fine granular carbon and carborundum. A quite recent patent to Mr. Acheson (U. S. Patent 702,758, of June 17, 1902), has for its subject-matter the particular manner of stacking such articles for graphitization, the granular carbon between the articles being the principal heat-producing agent, while the heat generated in the articles themselves is of secondary value because of the transverse position of the articles. By this arrangement the furnace charge offers such resistance to the current that it may

be held at a very high temperature, while the conducting terminals, of solid carbon, but of much smaller cross section than the furnace charge, are at only a moderate temperature. (This is also discussed by Townsend in the *Electrical World*, of June 28, 1902.) The current is then put onto the furnace, at 220 volts and 3,000 amperes to start with, and gradually increasing to 80 volts and 9,000 amperes at the end of a twenty-hour run. At the close of the run the furnace is allowed to cool off several hours before uncovering. The heat is thus sufficient to graphitize the furnace charge completely and also even some of the outer packing of granular carborundum. If the articles have not been heated sufficiently, they will still contain some amorphous carbon, which will dissolve in acids and alkaline solutions, and disintegrate the article; if they are overheated they may become too dense and develop cracks on cooling or subsequent use. Many hundred thousand of carbon electrodes, 15 inches long by 1 inch cross section, used in the liquid caustic alkali process, have been made in this way, and have given such satisfactory service that Mr. Acheson's business has really suffered by the surprising long life (one to two years) of these electrodes and the consequent paucity of renewals. Blocks, 8 inches by 10 inches and 4 inches thick, as well as rods, 4 inches square by 24 inches long, have been perfectly graphitized in these furnaces.

Since three to three and a half tons of material can be graphitized in one charge, with nearly an equal amount of granular carbon and carborundum on the furnace, we can calculate, from a consideration of the current used, that it would take the current used over sixteen hours to bring the furnace up to the volatilizing point of carbon, which is not far above the temperature of graphitization. The current being run for twenty-four hours, it follows that just about one third of the total heat energy of the current is radiated or conducted away during the run, while two-thirds are represented by the heat in the hot furnace at the end of the run, the heat in the actual articles being graphitized being 40 per cent. of the heat energy of the current. The conversion of amorphous carbon into graphite is, of itself, a heat-evolving reaction, such that the graphitization of 7,000 pounds of carbon would represent 7,000 × 230.5 = 1,655,500 pound-calories (1° C.) or some 5.7 per cent. of the energy which the current furnishes, but against this can be set the heat necessary to reduce metallic oxides and dissociate carbides, which will be a factor of about the same value.

As to the articles thus graphitized, they possess a specific resistance of but 0.00032 ohm per cubic inch, which is but one-fourth that of amorphous carbon. (This specific resistance is 0.0008 ohm per cubic centimeter, and since that of mercury is 0.0000094 ohm, the conductivity is 1175, mercury being 100, or 0.21, copper being 100). As for durability, such carbons have been used as anodes in alkaline chloride solutions for three years, with a current density of 50 to 250 amperes per square meter, without as much as rounding off the sharp edges. In electric-furnace work, at high temperatures, the consumption by oxidation is one-fourth, or less, that of



GRAPHITE FURNACES, ACHESON GRAPHITE CO.

amorphous carbons under similar circumstances, making their use in many cases very advantageous.

The other line which the electrical manufacture of graphite has taken, is the conversion of carbon in bulk into graphite. For this purpose some carboniferous material is taken which has a considerable quantity of ash, or metallic oxide impurities, uniformly distributed through it. The purest carbon, such as petroleum coke, which contains only 0.3 per cent. of ash, graphitizes very poorly; similarly, ordinary coke will graphitize completely only where the ash is uniformly distributed, but those parts of the coke which have been formed from the baking of exuded pure bituminous matter are too pure to graphitize and yield a poorly-converted product. Clean anthracite coal, such as washed *pea* or *buckwheat* coal are the best adapted, and give very satisfactory results, for in them nature has distributed 5 to 15 per cent. of ash with almost molecular uniformity.

The furnace for this conversion is 30 feet long and is formed of a trough 2 feet square, lined on bottom and sides with blocks

of compact carborundum 6 inches thick. This is found to be a very satisfactory lining for high-temperature electric furnaces, to build walls in places where the best fire brick would melt too easily and carbon bricks would be subject to oxidation. The coal is ground to about the size of rice and the furnace trough first half filled. Graphite rods are inserted in the ends, to conduct the current into the mass, and a core of granular carbon, partly graphitized, about 6 inches wide, is laid from one end to the other, in order to start the current, since cold anthracite is of itself so poor a conductor that, otherwise, it might be impossible to start the current flowing with the maximum volts at command. The furnace is then filled up, and a layer of coarse carbon and granular carborundum placed on the top. The charge of anthracite is about six tons, and it is graphitized in twenty hours. A consideration of the energy of the current and the amount of material treated lead to the conclusion that about 82.5 per cent. of its energy is consumed in raising the charge to the graphitizing temperature and 17.5 per cent. radiated during the run; or, stating it another way, it requires theoretically sixteen hours and thirty minutes' running to bring the whole charge up to the graphitizing temperature, and the rest of the twenty hours is used in keeping it there and supplying radiation. The heat *evolved* in conversion of amorphous carbon into graphite amounts in this case to fully 10 per cent. of the heat supplied by the current, but this is just about balanced by the heat absorbed in volatilizing the 5 to 10 per cent. of impurities from the coal.

The amount of unconverted amorphous carbon is most easily estimated in the laboratory by attacking it with concentrated nitric acid at 86° C., when the brown coloration of the liquid gives the means of estimating the amorphous carbon present. Natural graphite contains some amorphous carbon, say 0.1 to 0.2 per cent.; the manufactured graphite from anthracite coal may contain up to 2 per cent., the graphitized articles to which have been added iron oxide to facilitate conversion, contain often as little as the native graphite.

Many kinds of graphite may be produced from different carbonaceous materials treated in different ways and crushed afterwards in different manners. There is the soft and the dense, the laminated, foliated and stratified kinds, the fibrous, like Ceylon *wood* graphite and the scaly, like Ticonderoga graphite. Different kinds are suitable for different purposes; the scaly for crucibles and lubricating purposes, the dense for hard lead pencils, the soft for foundry facings, stove polishes and iron-protecting paints. The total yearly production of this factory is nearly 1,000,000 pounds, at an average value of 8 cents per pound; graphitized electrodes are valued at 12 to 15 cents per pound and graphite in bulk from 10 down to 4 cents, according to purity and flakiness, and the product represents a considerable fraction, some 20 per cent. of all the graphite produced in America.

### The Acker Process Co.

The projectors of this company are the brothers C. E. Acker and A. E. Acker, who began in 1894 experimenting at the problem of electrolyzing melted sodium chloride, and producing thereby caustic soda and chlorine. An extensive description of the process which has been evolved, written by C. E. Acker, is in the *Transactions of the American Electrochemical Society*, Vol. I, 1902. The patents under which the company work are U. S. Patents 649,565, of May 15, 1900; 674,691, of May 21, 1901, and 687,709, of December 3, 1901, to Chas. E. Acker.

The plant established at Niagara Falls is situated 1,500 feet below the lower power house, on a 10-acre piece of ground, and comprises a large reduction room, some 80 by 150 feet in plan, a still larger building of brick and iron for the bleaching powder plant, besides an extensive machine shop, brass-casting foundry, pattern shop and large offices. Some 250 men are in the company's employ.

The idea of Acker's process, and elaborated in his patents, is the electrolyzing of melted sodium chloride resting upon melted lead, the latter serving as cathode. The lead-sodium alloy is then decomposed by a jet of steam in another part of the same apparatus, producing melted caustic soda, which flows away and hydrogen which immediately burns. The process is carried on in a heavy cast-iron vessel, 5 feet long, 2 feet broad, with a bowl about 12 inches deep. The sides, above the surface of the melted lead lying on the bottom, are protected by a lining of magnesia blocks. At one end is a small compartment separated by a partition dipping below the level of the lead, into which the lead alone can pass and in which

ACKER PROCESS CO.

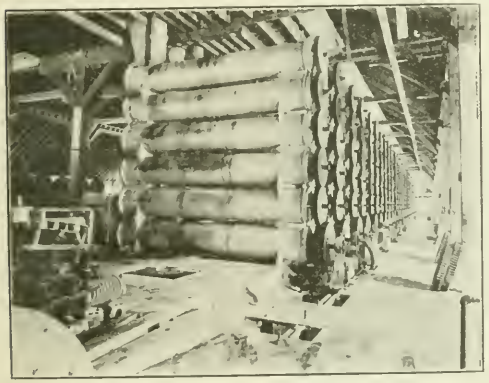
it meets a jet of steam blown directly into it, which oxidizes the sodium to caustic. On top of the lead a bath of sodium chloride is melted, about 6 inches deep, into which dip four graphitized carbon blocks serving as anodes. The lower surface of these blocks are 14 inches long by 7½ inches wide, and reach to within ¾ inch of the melted lead. The blocks are 3 inches thick and are kept in place by heavy 5-inch round graphitized carbons, 12 inches long, two of which are screwed into each carbon block. The upper end of these rods are encased in fire-brick tiles, which, when in place, form part of the cover of the furnace, and electrical connection is made by

ACKER PROCESS CO.

means of heavy brass rods, 1½ inches in diameter, tapped into them, and connecting further up with copper rods, which are held by clamps to the bus bar above. The 5-inch rods are protected by fire-clay sleeves, joints are plastered over with cement. The top of the furnace is further loosely closed by fire-clay slabs, but the joints need not be very tight, since the chlorine is drawn away by side flues by a strong exhaust, making the escape of chlorine into the room impossible. The

salt to be used for charging comes through a hopper from the floor above, and is piled between the furnaces and on part of the cover, so as to become dry and warm before being charged.

The pot room has place for 54 furnaces, in four rows, of which 40 to 45 are in action while the others are undergoing repairs. The current of 3,000 horse-power is sent 1,500 feet from the generating station as direct current of 8,200 ampères, reaching the works at a potential of 275 volts, the cables in the conduit being half the way copper and half aluminum. The pots are all run in one series, so that the drop of voltage is between 6 and 7 volts per pot. The four electrode blocks carry, therefore, about 2,100 ampères of current each, which gives a current density at the lower surface of approximately 2,750 ampères per square foot. This keeps the temperature of the bath at 850° C., a cherry red, which is 75° above the melting point of the salt. The object in conducting the process is to keep as nearly as practicable to the melting point of the salt, in order to avoid the re-solution of sodium and the re-combination which takes place at higher temperatures. The melted salt looks slightly syrupy, and has a silky sheen like melted metal. The workmen regulate the temperature by raising or lowering the electrodes and by charging fresh salt as



BLEACHING POWDER CYLINDERS, ACKER PROCESS CO.

the level of the bath sinks, and they have frequently to break with a bar the crust which solidifies between the carbon rods. The salt is from the neighboring New York salt beds, costs $3 per ton and is not purified before use. The bus bars, for carrying the current, are of copper, and of 9 square inches section, giving 900 ampères per square inch, which is very ample carrying capacity, since aluminum conductors, with only two thirds the conductivity, are sometimes loaded quite as heavily

The steam jet, in the compartment at the end of the pot, is introduced beneath the surface of the lead, but pointing vertically upwards. The jet strikes a curved hood, which brings the material down into a third compartment, about 6 inches by 10 inches in area, in which the lead and caustic separate, the latter flowing out of the furnace over a cast-iron lip, the lead sinking and passing back into the reduction compartment of the furnace, while the hydrogen evolved issues from the spout, burns and is conducted away by a 6-inch sheet-iron pipe to a chimney. The melted caustic runs into a sheet iron pan, where it sets, and is removed every hour. The average output of a furnace is a 25-pound cake hourly. The theoretical amount of caustic which the current should produce being 26.9 pounds per hour, in each pot, the average efficiency obtained is thus seen to be 93 per cent. The voltage used, however, is the other factor of the process which needs considering. There is required, theoretically, 4.2 volts to decompose sodium chloride into sodium and chlorine, but since the sodium unites with lead with great avidity, it is probable that the production of the alloy requires 3.5 volts. Since 6 to 7 volts are used per furnace, we have an average of 3 volts converted into heat. Of this heat evolved, calculation shows that one-sixth is utilized in melting the fresh salt added, while five-sixths is lost by radiation and conduction, and resistance of conductors and connections. Or, considering the whole energy of the current, we may say that 54 per cent. of it is utilized in the chemical reaction, 7 per cent. in melting the salt added and 39 per cent. is lost by radiation and conduction.

The cakes of solidified caustic are taken out of the pans and slide down a chute directly into the cast-iron melting pots, 8 feet in diameter. Here it is melted, allowed to stand six hours to settle and bailed out into sheet-iron drums, 2 feet in diameter by 4 feet high, holding 750 pounds each. The total product is 23,000 pounds of caustic per day.

The chlorine gas is drawn by a powerful fan, 15 feet in diameter, motor driven, through a series of 30 Hassenclever absorption apparatus, each consisting of six drums above each other, 2 feet in diameter by 20 feet long, in which screens revolve slowly in alternate directions. The 50 pounds of slaked lime fed per hour into the upper cylinder is gradually passed by the screw motion from one cylinder to the other, until in twenty four hours it arrives at the discharge hopper, while the chlorine gas, mixed with air, passes in the opposite direction through the apparatus and into a scrubbing tower beyond, where the last traces of chlorine are removed. The total plant takes care of 21,000 pounds of chlorine daily, requiring 36,000 pounds of slaked lime and producing 57,000 pounds of bleaching powder.

With salt costing $3 per ton and power $15 per horse-power per year, the cost of raw material for making a ton of caustic soda is $4.50, the cost of power $11, steam and remelting 50 cents, labor and repairs probably $14 or an estimated total of $40, which is to be diminished by the value of the chlorine for making bleaching powder. Every $1 per ton profit made on the sale of the bleaching powder would mean $2.50 per ton reduction on the net cost of the caustic. Compared with the aqueous processes, Acker's process consumes more power and costs more in replacement of apparatus, but takes less expensive plant and apparatus, and dispenses with the boiling down of the caustic solutions.

We wish success to the manufacturers in both lines

## STATISTICAL.

In a circular, issued by the authorities of the Universal Exposition to be held in St. Louis in 1904—Prof. W. E. Goldsborough being the chief of the Department of Electricity—the following statistical data are given:

Number of electroplating establishments, 500.

Capital invested in electric mining and power transmission properties, $200,000,000.

Capital invested in electroplating and depositions, $50,000,000.

Capital invested in "automobile and electric storage batteries," $25,000,000.

Total amount invested in electrical industries, $3,975,000,000.

Electrolytic production of copper, 200,000 tons per year

Electrolytic production of gold, 170,000 ounces per year

Electrolytic production of silver, 12,000,000 ounces per year

It is not stated whether these figures refer to the United States alone, or to the whole world. But from the figures given for the electrolytic production of copper, it is evident that the United States alone is meant. The figure for the electrolytic production of silver does not seem to be correct, as in the latest volume of *Mineral Industry* (Vol X, page 228) the estimated daily output of three electrolytic silver refineries, in operation in the United States in 1901, is given to be 125,000 ounces Troy. If one assumes only 300 working days per year, the yearly amount of electrolytically-refined silver comes out as 37,500,000 ounces, *i. e.*, more than three times the amount stated in the pamphlet.

## PIONEERS OF ELECTROCHEMISTRY—II.

Alfred H. Cowles.

Alfred Hutchinson Cowles, second son of the late Edwin Cowles, founder and editor, until his death, of the Cleveland *Leader*, was born in Cleveland, Ohio, in December, 1858. His mother, Elizabeth Hutchinson Cowles, fully shared her distinguished husband's appreciation of education, and Alfred Cowles, like his brothers and sisters, was given large opportunities to follow his bent for study. He attended the public schools of his native city, and later he spent two years at the Ohio State University, at Columbus, making chemistry and metallurgy his special studies. From this institution he went to Cornell University, and remained there four years, continuing to devote himself to science.

At Cornell Alfred Cowles became active in rowing, being the captain of the 'varsity crew in his senior year, and going with it to Europe, where the Cornell oarsmen raced at Henley, for the famous Stewards' Challenge Cup, at Putney and on the Danube. But chemistry, metallurgy and physics remained the chief interest of his life, as they have been to the present date.

Alfred H. Cowles

After leaving college, Mr. Cowles spent some time in New Mexico, in the development of mining property owned by his father. When hardly more than a boy he invented an improved backing, still in general use, for matrices in newspaper and other stereotyping. Then, as at all times since, science and invention left room for the general interests of a man of affairs, largely interested in a great newspaper and accustomed from childhood to the consideration of public questions and important concerns of many kinds.

But the chief pursuit and interest of seventeen years for Mr. Cowles has been the electric smelting of aluminum and the researches and discoveries in electrochemistry and physics which have attended and grown out of that central subject of study and experiment. In connection with Eugene H. Cowles, an older brother, the subject of this sketch revealed and developed the great possibilities of the electric furnace, especially in the production of aluminum and alloys of that metal. The Cowles Electric Smelting and Aluminum Co. were organized and works were built in 1885 at Lockport, N. Y., where extensive water-power could be obtained. By means of the electric furnace, first used commercially by Alfred and Eugene Cowles, and brought by them before the world of science, as well as business, alumina and many other minerals, some of them rare and refractory, were disrupted for the first time by any other than a chemical laboratory process.

Patents were taken out in Great Britain, Germany and other foreign countries, and a company were organized in England to produce aluminum and its alloys.

Between 1885 and 1890 the Cowles Co. offered aluminum, for the first time anywhere in the world, in cheap form and commercial quantities, although almost wholly in alloys, especially bronze.

Out of this business sprung many important discoveries in electrochemical smelting. Among the results are calcium carbide, which is said to have been produced, in a small way, in the Cowles electric furnace while it was used in Cleveland. Thomas L. Willson, who was then employed in the Brush Electric Works in that city, later developed the production of calcium carbide on a commercial scale at Spray, N. C., and from this source, since greatly enlarged and improved, has come the supply of acetylene gas for various purposes.

Carbon bisulphide is now made on a large scale at Penn Yan, N. Y., by Chas. B. Taylor, formerly of Cleveland, by the adaptation of the electric furnace to an industry which depended, until that furnace came into use, on chemical means of production. At Niagara Falls phosphorus is produced by a process which is said to be an outgrowth of the Cowles discoveries. It is the direct result of the researches and inventions of Dr. Redman, employed at the works of the British "Cowles Syndicate" when that company were located at Stoke-on-Trent.

Another notable development from the electric furnace has been the carborundum industry, now attaining large proportions at Niagara Falls. In 1890 Edward G. Acheson, a young student and experimenter from the laboratory of Thomas A. Edison, undertook, by the use of the electric furnace, to make diamonds. He produced hard, lustrous crystals, composed of carbide of silicon, and found them commercially available as a substitute for emery and other abrasives. From this beginning an important business has developed, but it is said that the foundation for it was laid in 1884, when Alfred Cowles and his brother, now many years deceased, are said to have first produced carborundum in their electric furnace in Cleveland.

In the early days of the Cowles Electric Smelting and Aluminum Co. their experiments and improvements did important pioneer work for the United States and for other countries in the use of large dynamos.

The development of the aluminum industry by the Cowles Co. has been much impeded by prolonged and costly litigation, begun in 1891, over certain fundamental patents. Four great cases have been contested in the United States courts, and two have been carried to a final decision in favor of the Cowles interests. The others are awaiting a hearing in the Circuit Court of Appeals, after decisions adverse to the Cowles side in the lower courts.

The work of Cowles has resulted in the production of many articles in common use, from the lamps on bicycles to aluminum for the transmission of electric energy.

Alfred H. Cowles is still active and fertile in scientific research, and his studies run into fields of investigation and discovery widely different from that which has been the main interest of his life.

# NIAGARA FALLS MEETING
OF THE
# AMERICAN ELECTROCHEMICAL SOCIETY.

THE second general meeting of the American Electrochemical Society, held at Niagara Falls, N. Y., from September 15th to 18th, turned out to be a splendid success in every respect. The actual attendance at several of the meetings was nearly 200, while the number of members and guests registered was 164, an alphabetical list of the latter being given on another page of this issue.

The local committee, comprising the Niagara Falls members of the Society, with Chas. M. Hall as chairman, and a ladies' committee, with Mrs. Chas. E. Acker as chairman, had arranged an extensive programme for the different days of the meeting, and did everything in their power to make the visitors feel at home. A search-light trip over the Niagara Gorge trolley line to Kingston and back, on the evening of September 16th, was especially enjoyable. On the evening of September 17th the local committee gave an elaborate banquet to the members and guests of the Society at the International Hotel. This was followed by dancing in the hotel parlors. Wm. B. Rankine, who presided as toastmaster at the banquet, responded to the toast "Niagara Falls;" President J. W. Richards to the toast to the Society; Prof. Haber spoke for the German Bunsen Society and R. S. Hutton for the electrochemists in Great Britain; Prof. W. D. Bancroft responded to the toast "Our Universities;" Prof. F. B. Crocker to a toast on the sister societies, and Dr. N. S. Keith to a toast on the ladies. The banquet was attended by 150 persons.

Some disappointment was being felt on account of the fact that the managers of most of the electrochemical plants of Niagara had previously decided to keep up their old policy of secretiveness, and not to open the doors of their workshops to the members of the Society. Only four electrochemical works made an exception, and their courteous invitation was greatly enjoyed. They were the International Acheson Graphite Co., the Carborundum Co., the Electrical Lead Reduction Co. and the Atmospheric Products Co. The same courtesy was extended by the Niagara Power Co., the Hydraulic Power and Mfg. Co. and the Natural Food Co. The visits to these plants were very enjoyable, and while they represented only a small percentage of all the plants, it is perfectly true that on the whole the members of the Society saw more in Niagara than they can ever see at any other single place in the United States.

From official statements given out at the meeting, it appears that the financial conditions of the Society are in a fairly good shape. The number of members, including the applicants to be elected at the next meeting of the Board of Directors, is 433. The New York members, through A. von Isakovics and Dr. N. S. Keith, extended a courteous invitation to the Society to hold the next meeting in New York City, in the spring of 1903. This meeting will be the annual business meeting, while the Niagara convention was devoted entirely to scientific and technical matters. Technical sessions were held on every morning of the four days the convention lasted, and, in addition, in order to get through the whole programme of papers, it became necessary to hold a session on the afternoon of September 17th. In the following we give a concise review of the proceedings:

## MONDAY'S SESSION.

The first paper presented to the Society was by Francis A. J Fitzgerald, on "Testing Carbon Electrodes." He discussed methods used by the Acheson Co. for determining the density of a carbon electrode and for determining the amount of amorphous carbon in a graphite electrode. A long abstract of this interesting paper is given on another page of this issue. The paper was discussed by Messrs. Hart, Hutton and Keith. Professor Hart suggested the use of persulphates for distinguishing between amorphous carbon and graphite in a similar way as they are now used in the determination of manganese in steel. Mr. Hutton called attention to the different behavior of graphite made in different ways, principally by dissolving the carbon in different metals. This was confirmed by Mr. Fitzgerald, who said that there are as many kinds of graphites as there are of amorphous carbon, and that the subject is really a very vast one.

The next paper was read by Dr. J. W. Richards, on "The Efficiency of Electric Furnace Operations." A longer abstract of this paper is given on another page of this issue. The paper was discussed by Messrs. Hering, Bancroft, Hart, Whitney and Haber. Mr. Hering pointed out that the determination of the efficiency requires the knowledge of the theoretical amount of energy necessary for a given process, and that this theoretical amount is often not definitely known. For instance, in the case of calcium carbide, the theoretical values given by different authors vary greatly. In reply to a question on the possibility of reducing the radiation loss by getting up the walls of the furnace in such a way as to leave small air chambers throughout the wall, Professor Richards replied that he thinks it is better to relatively reduce the radiation loss by increasing the size of the furnace and working at a faster rate.

The next paper on the programme, by P. G. Salom, on some improvements of the process of electrical lead reduction, was not read, on account of pending patents. It was promised for the next meeting. The theoretical problems involved in this process were, however, discussed at length in an interesting paper presented by A. J. Weightman, on "Cathodic Reduction." A longer abstract of this paper is given on another page of this issue. It elicited an animated discussion, in which Messrs. Reed, Keith, Hering, Rodman, Haber, Hutton and Blackmore participated. Mr. Reed did not think that it is necessary to have recourse to Caspari's theory of the overvoltage. He claimed that Weightman's results could be explained by the simple rule that where there is a mixture of cathodes (*i. e.*, where the cathode contains two materials capable of reduction) the current divides itself between the two in a proportion depending upon the accessibility of these two cathodes. On the other hand, Professor Haber held that such considerations do not overcome the difficulty, that hydrogen will not develop on the cathode without overvoltage. He suggested that there might be intermediate steps between the formation of gases from ions, such as solution, adsorption, the formation of an alloy, etc.

The last paper of this session was read by Dr. Louis Kahlenberg, on "Differences of Potential between Metallic Cadmium and Solutions of Cadmium Iodide in Various Solvents." Cadmium iodide was used as the solvent, because it is readily obtained in a pure anhydrous form, and is soluble in a goodly number of solvents, the resulting solutions often being fair electrolytes. As solvents, mostly nitrites and amines were used. The concentration used was 0.1 gram equivalent per liter, or concentrated solutions were used in case the salt was not sufficiently soluble. The difference of potential between metallic cadmium and the solutions of cadmium iodide was measured against Ostwald's normal electrode (a normal solution of potassium chloride in contact with an excess of mercurous chloride and metallic mercury). The cadmium was always the negative pole. The e. m. f. of the normal electrode was assumed to be — 0.56 volts, and the e. m. f. at the junction of the two liquids was neglected. The principal result of his measurements may be stated as follows: The difference of potential between a metal and a solution is

determined by the chemical affinity between the metal and the solution. Differences of potential between a metal and a solution of the same strength in solvents that are chemically very different are of the same general order of magnitude, though they are by no means identical.

Before this session was closed, Dr. C. A. Doremus called attention to the International Congress for Applied Chemistry, to be held next June, in Berlin, under the auspices of the German Government. Dr. Wiley, of the United States Department of Agriculture, forms a committee of organization for America. An important section of the congress will be the electrochemical section. He moved to request the Board of Managers to take action regarding the appointment of delegates to this congress. The motion was carried.

During the afternoon the visits to the various plants, mentioned above, took place.

## TUESDAY'S SESSION.

The first paper of this session was by Marcus Ruthenberg, on "Developments in the Electrometallurgy of Iron and Steel." In the absence of the author it was read by Dr. E. Hart. A longer abstract of this paper will be published in our next issue. It was discussed at length by Messrs. Hart, Keith, Johnson, Hering, Reed, Salom and Richards. Dr. Hart mentioned a process by Blake of electric (not magnetic) concentration, used in an experimental plant of Schwartze, in Denver. The small particles of ore are charged electrostatically. Some of the particles take the charge more rapidly than others and lose it less rapidly. This gives a new principle of separation, the quantity of energy required being quite small. Moreover, it is possible to separate, in this way, particles which cannot be separated very easily by water concentration, because of their fineness. He thought that Mr. Ruthenberg takes too sanguine a view of the possibilities of the electric furnace in iron smelting, as it should not be forgotten that to-day the iron-smelting furnace is absolutely the most economical furnace in existence. Other speakers also expressed the opinion that the electric furnace for iron and steel has the very great handicap of high cost. Dr. Keith referred to Edison's efforts in magnetic separation. Mr. Reed remarked that Edison's problem is a very difficult one, as he starts with an ore which contains on an average about 20 per cent. of iron; the rest is rock, and there is also a large amount of phosphorus. The ore must first be ground to a very fine mesh; then the phosphorus is removed; then follows washing, drying and briquetting before the ore can be concentrated in the magnetic separator. These various processes make the product quite expensive. Mr. Reed believed, however, that magnetic separation is quite economic for certain kinds of ore, which exist in immense quantities, and have only to be ground to a quarter or one-eighth mesh, and then merely have to be run through a magnetic separator, without requiring further treatment. Mr. Salom expressed the opinion that there is not much danger in the immediate future of the electric furnace superseding the blast furnace as a method of manufacturing iron or steel, although the possibilities of it are not to be ignored in the future. He also thinks that, in view of the enormous amounts of high-grade ores that are still in existence, all the attempts at concentration processes will be a failure until the good ores become scarce. It does not pay to operate 5 and 10 per cent. ores when one can get 50 and 60 per cent. ores. Magnetic separation may, however, be economic with ores below 50 per cent., and containing a large amount of phosphorus. It pays to bring them up to over 50 per cent. and get rid of the phosphorus.

The next paper was read by Dr. Eugene A. Byrnes, on "Voltaic Cells with Fused Electrolytes." The author gave the results of a great number of measurements of the e. m. f's of voltaic cells of the type generally called a "carbon cell." The electrolyte used throughout was primarily sodium hydroxide, contained in an iron or other vessel and maintained in fusion by a gas furnace. The electrodes were of carbon, especially graphite, and of various metals. In one set of experiments, both electrodes were introduced into an open vessel containing the molten sodium hydroxide. In the other set of measurements, the molten caustic was divided into separate portions by a porous cup, and various oxidizing agents or depolarizers were supplied to the portion containing the cathode. The porous cup was made by taking two concentric cups of perforated sheet iron, separated by a space of 1 cm., this space being filled with "an oxide" in granular form. Concerning the results of the measurements—which mostly gave e. m. f's much smaller than 1 volt—the reader must be referred to the full paper, which will be published in the "Transactions of the Society." Some of his results are in fair agreement with former results of Liebenow and Strasser. In the discussion of the paper Mr. Reed remarked that he believed the e. m. f. of such cells to be mostly thermo-electric. Dr. Byrnes, in his reply, did not deny that there may be a thermo-electric effect, but it is only partial and not the principal effect.

The next paper was read by R. S. Hutton, of Owens College, Manchester, England, on "The Fusion of Quartz in the Electric Furnace," for the purpose of making quartz fibers and small tubes for scientific purposes. A transparent, glass-like substance is produced, which has an exceedingly small coefficient of expansion and a high melting point. In the first attempts of heating quartz in the electric arc, chemical changes were observed, reduction to silicon and carborundum. If precautions are taken, however, to insure an oxidizing atmosphere around the quartz, it can be easily fused by the arc without any complications. He first experimented with a small open arc, with a magnetically-deflected flame, but this method is not suitable for working at a large scale. He later experimented with a small laboratory electric furnace of the Moissan type, using a direct current of 300 to 500 ampères, at about 50 volts. The method used consists essentially in making a mold and casting the tube in this mold. The mold consists of a graphite block, and is grooved out. As an axis, a small graphite rod, of the diameter of the bore of the tube required, is supported on end pieces. The mold is fed gradually under the arc, the portion immediately underneath becoming very quickly fused, when the carbon is advanced little by little, until the whole mass is fused along its entire length. The mass thus produced always contained a large number of small inclosed air bubbles, which greatly impair its transparency. He also tried the following method: A carbon rod, or carbon of any other shape required, is brought to white heat by passing an electric current through it, the carbon being surrounded by sand or finely-divided quartz crystals. In this way, in almost a moment, the heating is sufficient to cause a powerful agglomeration of the particles of silica in the neighborhood of the heated carbon, and although by the process the material only becomes melted just at the inside, near the carbon, he believes such a method would be useful for forming a tube or other shaped masses which can afterwards be treated. Mr. Hutton's paper was discussed by Messrs. Whitney, Bancroft, Fitzgerald and Doremus.

The next paper was read by Prof. Henry S. Carhart, on "A Thermo-electric Theory of Concentration Cells." The paper was an extension of the theoretical considerations given in the author's paper published in Electrochemical Industry last month. The author showed how both Nernst's theory and Helmholtz's formula led to the definition of a concentration cell as a device for converting heat into electrical energy. For the understanding of a concentration cell, it is therefore necessary to study the thermo-electric forces at the two electrodes. He has discovered the law that the thermo-electric force increases with the concentration of the solution. According to his theory, the e. m. f. of a concentration cell is represented by the difference of the two thermo-electric forces at the electrodes, and this difference is not zero, because the thermo e. m. f. at the concentrated solution is greater than at the dilute solution. He exhibited very interesting curves, and made an application of his results to the theory of the Daniell

cell. The paper elicited an animated discussion, in which Messrs. Bancroft, Haber, Hering, Kahlenberg, Carveth, Patterson, Weightman, Reed, Richards and Keith participated. Professor Haber claimed that Helmholtz's formula and Van't Hoff's formula, taken together, explain completely anything concerning the theory of a concentration cell. Mr. Weightman had made some experiments with the nickel cell described by Professor Carhart in a former paper. He short-circuited such a cell, and found that he did not get a deposition of nickel at all in the dilute solution, and that although the electrode in the strong solution lost a certain amount of weight, it did not go into the solution as a sulphate.

The next paper was read by Carl Hering, on "An Apparent Electrochemical Paradox." He described a curious experiment which he and Mr. Reed made some years ago, in which water was decomposed in visible quantities at voltages far below the theoretical value (about 1.45 volt), even as low as about 0.3 volt. This seems to contradict the law of the conservation of energy, as these gases in re-combining could generate more than this amount of energy. The experiment consisted in electrolyzing acidulated water in a strong N-shaped glass tube, which was sealed at both ends and provided with a bend containing mercury, which enabled the mechanical pressures to be read off. The results were shown in a curve. The pressures reached about 23 atmospheres, when the tube exploded. The voltage at the terminals, when a constant current passed, diminished rapidly and very decidedly to about 0.3 volt at about 16 atmospheres, and then remained practically constant. Allowing for the loss due to resistance, the actual voltage of decomposition was even much lower, nearly zero. There was visible gasing during the whole test, showing that water was really being decomposed. The increasing pressures also showed this. No researches were made to find the correct explanation of this curious result, the intention of the paper being merely to describe the experiment. A possible explanation was, however, suggested, showing how the results need not be inconsistent with Faraday's law or the law of the conservation of energy. It is based on the assumption that some of the gases liberated at one electrode probably passed mechanically to the opposite electrode, which they could easily do in suspension, as the electrodes were very close together. These were then consumed as depolarizers, and this depolarization lowered the voltage. The paper concludes with a suggestion of an experiment in which water is electrolyzed in a strong sealed vessel which is completely filled, so as to leave no room for the gases. Some curious results may then be expected. Mr. Hering's paper was discussed at great length by Messrs. Rodman, Johnson, Carhart, Reed, Hutton, Burgess, Bancroft, Kahlenberg, Haber and Richards. Some similar experiments were mentioned, and in general the explanation given by Mr. Hering seemed to be accepted by the speakers.

## WEDNESDAY'S TWO SESSIONS.

The first paper of the morning session was read by Prof. W. E. Goldsborough, on "Electrochemistry at the World's Fair, St. Louis, 1904," a longer abstract of which will be published in our next issue. The paper was a strong plea for co-operation of the Society to make the exposition a great success in the electrochemical department. The aim will be to make the people of the country at large familiar with the applications of electrochemistry. Processes will be shown in operation. He urged manufacturers to exhibit model plants which show the principle of the process in working. They may embody only the fundamental and essential points of the process, and may differ in many details from the actual process as worked on an industrial scale, so that no trade secrets are revealed. The address was heartily applauded, and the following resolution, proposed by Carl Hering, and seconded by Messrs. Carhart and Coho, was then unanimously accepted by the Society:

"Whereas, The American Electrochemical Society, in convention assembled, recognizes the great international importance of the Louisiana Purchase Exposition, and feels that it will do much in placing before the people of the world a true picture of our national progress; and,

"Whereas, In no branch of our scientific or industrial progress have greater developments taken place recently than in the field of electrochemistry;

"*Resolved*, That the American Electrochemical Society hears with great satisfaction the announcement that steps are being taken looking to the organization of a fine and comprehensive exhibit in the group of electrochemistry, and offers assurances of hearty good-will and co-operation in the accomplishment of this much to-be-desired end."

The next paper was read by Dr. H. T. Barnes, on "The Theory and Practice of Continuous Flow Calorimetry." The method discussed in this paper has been worked out with great care in the last five or six years. It is useful for actual calorimetric measurements in the laboratory, and to show the relationship between electrical and heat units. It is to be used in connection with the Weston electrical instruments. In principle the method consists in having a flow of liquid continuously heated by an electric current in a fine flow tube. The liquid is allowed to flow until the temperature conditions have become perfectly steady. The temperatures of the inflow and outflow and the e. m. f. and current are then measured. The method has been elaborated with the greatest accuracy, and is an interesting example of the high accuracy which can be obtained in the experimental methods of modern physics. The author discusses the sources of error, and shows how they are eliminated. To mention only one detail, the heat wire is in the form of a spiral, in order to break up the stream lines in the liquid, which is very important. The paper was discussed by Messrs. Kahlenberg, Cowles, Hutton, Potter, Whitney, Carhart and Patterson. Mr. Potter suggested a somewhat different mechanical construction. Professor Carhart pointed out the great exactness of modern methods of measurements, indicated by the fact that Barnes' measurements lead to results which agree exactly with Carhart's determination of the e. m. f. of the Clark cell.

The next paper was read by Woolsey McA. Johnson, on "The Electrolytic Dissolution of Soluble Metallic Anodes." A longer abstract of the paper, which is an interesting discussion of several points of the theory of electrolytic refining processes, is given on another page of this issue. The paper was discussed by Messrs. Bancroft, Keith and Reed. Dr. Bancroft corrected a mistake in an assumption made by the author, and Dr. Keith claimed that the alleged difficulties in processes of electrolytic refining do not exist in reality.

Arvid Reuterdahl then read a paper on "The Electronic Hypothesis and its Applications." This paper was a continuation of the discussions started by the author in a paper read before the Society at the first meeting, in Philadelphia. Like the former paper, his present paper is rich in sarcastic and amusing remarks on the very artificial assumptions often made by theoretical physicists, in order to save a theory; for instance, the various assumptions concerning the properties of the ether, etc. The author first discusses the phenomena which have led to the hypothesis of electrons. One point to which he called strongly the attention of the hearers was that an electron is assumed to represent not only an electric charge or quantity, but also to have a mass. He claimed that the latter point is often forgotten by theoretical physicists in applying the hypothesis of electrons. In the second part of his paper he spoke at length of the law of gravitation, and attempted to prove that it is too one-sided, because it speaks only of attraction. He wants to substitute for it the electric law of inverse squares and claims that all difficulties then disappear. In the discussion which followed Dr Whitney made some remarks on experimental researches begun by him with the intention to detect positive electrons. Professor Carhart entered a strong protest against at least one of the critical remarks of Mr. Reuterdahl on difficulties of the molecular theory, and said that these difficulties had long ago been satisfactorily explained

by Clausius. Mr. Reuterdahl, in a brief reply, insisted on the position he had taken in his paper.

Hugh Rodman then read a paper on "Storage Battery Invention," which is essentially a critical comparison of the lead cell and the new Edison cell. A longer abstract is given on another page of this issue. The paper was discussed by Mr. Reed, Dr. Keith and others. Dr. Keith expressed the opinion that the inherent difficulties which the Edison is claimed to have are more alleged than real. Mr. Reed said that if certain reports of the daily press concerning actual runs of automobiles with Edison batteries are correct, then the problem has been completely solved by Edison. It appeared, however, that most of the speakers were somewhat skeptical concerning the exactness of those newspaper reports.

In the afternoon session the first speaker was Dr. F. Haber, professor of the Institute of Technology, in Karlsruhe, Germany. As the official delegate of the German Bunsen Society, he brought to the American Electrochemical Society the good wishes and greetings of the German sister society. He then read his paper on "The Phenomenon of the Formation of Metallic Dust from Cathodes." He has studied for several years this phenomenon, which seems singular at first sight, but is of greater general importance. He showed two experiments in which he sent the current from 20 storage batteries through a cell containing a 20 per cent. solution of potassium hydroxide. In both experiments an iron nail was the anode, while the cathode was a nail of lead in the one case and a nail of tin in the other. When the current is closed, a black cloud of dust goes off from the cathode, and is distributed in suspended form throughout the solution, so that it finally looks like ink. The cloud consists of dust of the material of the cathode. This phenomenon takes place when the current density at the cathode is sufficiently great. The explanation of the phenomenon is as follows: The cation of the solution forms an alloy with the metal of the cathode. This alloy contains a relatively high percentage of the alkali metal, if the current density at the cathode is high enough. It can be shown, however, that such an alloy cannot exist in contact with water or a caustic alkali solution. If such an alloy is prepared by a purely chemical method, and is brought in contact with water, exactly the same formation of dust occurs. Hence, in his experiments, the electrochemical action consists in bringing the alkali metal cations to the cathode; they form an alloy with the metal of the cathode, and, by secondary chemical action, this alloy is decomposed and the formation of dust takes place. When the cathodic current density is high, rich alloys are formed, and the formation of dust takes place. When the cathodic current density is low, the alloys will be poorer; there is no formation of metallic dust, but the surface of the cathode shows signs of having been attacked. Similar experiments have been made with lead and bismuth cathodes in acid solutions. An alloy of hydrogen is formed in this case, which is rapidly decomposed in contact with water, and gives off hydrogen.

The paper was discussed at length by Messrs. Keith, Bancroft, Carhart, Kahlenberg, Reed and Richards. Dr. Bancroft suggested that there might be a connection between this phenomenon and the fact that certain cathodes have a greater reducing power than others. Dr. Haber confirmed this, but stated that it is difficult to say exactly what the relation is between the alloy formed and the change of the reducing power. Mr. Reed had previously described the same phenomenon. Professor Carhart described the following method of producing a very firmly-adhering layer of platinum black on platinum: He decomposes zinc sulphate with a very small current, say 0.1 ampère and 50 square centimeters surface of platinum cathode, for five or six hours. Afterwards the circuit is broken and the platinum plate is left in the solution; in some hours it turns black. The explanation is that an alloy of zinc and platinum has been formed, which cannot exist on account of the free acid present in the solution, and is then decomposed. Dr. Kahlenberg remarked that well-adhesive electroplating deposits can only be obtained if first an alloy is formed.

The next paper was read by Alfred H. Cowles, on "Certain Electrical Units," suggested in order to co-ordinate mass quantity with electricity quantity, and for use in tracing energy in its transformations accompanying chemical reactions. The paper was interesting, as it showed some very simple numerical relations which enable the author to suggest a new system of units for practical purposes. The author goes even further; he endeavors to prove that those simple numerical relations are not merely accidental, and he tries to find their deeper unknown significance. This part of the paper is strikingly original, and shows the characteristic qualities of the pioneer who goes ahead and asks: "Why is it?" where others would simply speak of an accidental coincidence, and would not care to look for deeper unknown causes. True, Mr. Cowles has not yet found the last connecting link which would prove that there is really a deeper significance in the relation found by him, yet, as he is convinced that it exists, he is right in speculating to find it, for "if you do not speculate you can never strike the truth."

The author considers units as "measuring tools for use in reasoning," and points out that for special subjects, like electrolysis, they should be of such convenient dimensions as not to be cumbersome. He has found that, as a coincidence, 500 ampères in one day (12,000 amp. hours) decompose practically (within 1 per cent.) a pound molecule of any univalent compound. The convenience of this close relationship suggests the idea of making it the basis of a unit, the *pound Col.* While this unit is of the same nature as the conlomb, it has merged in it the day as a larger unit of time. He then discusses the proportionality which exists, according to Faraday's law, in electrolysis between the quantity of electricity and the mass, if the latter is measured by gram equivalents. In the light of the relationships which are known to exist between conductivity in electrolysis, osmotic pressure, vapor tension and the raising and lowering of melting and boiling points, he thinks it would be of value to have a set of units of electrical quantities related to or dependent upon a unit quantity, by weight and volume, of hydrogen, which in turn is related to the gram and the c. c. of water by a constant figure. He has found that 100 ampères in one day free 1 c. c. of hydrogen ,and he says that when figuring out this from the most reliable esperimental data one finds this relation to be exact. He therefore suggests to make this a new unit, and, as the weight is a kilocrith, he calls it a kilocrith Col. He suggests a whole system of new units. For instance, he proposes to create a table of "apparent relative atomic capacities for electricity," similar to the table of atomic weights. From such a table thermal reactions or energy transformations would be read with the same ease that we now read and trace the shifting of mass in chemical reactions. It is this relation—that 100 ampères in one day free 1 c. c. of hydrogen—which the author discusses in the second part of his paper, endeavoring to find a physical reason for this relation. It is evident that this must be an extremely complicated matter, as here very different units of physical science are interlinked. Mr. Cowles goes on to put together the relations existing between the units which enter into the problem, but, as mentioned before, he is unable to find the last connecting link. Concerning the details, we must refer the reader to the full paper, which will be printed in the "Transactions of the Society."

The paper was discussed by Messrs. Whitney, Bancroft, Hering, Reed, Richards and Keith, most of whom considered the relations pointed out by Mr. Cowles to be very interesting, but accidental.

The last paper of this session was read by Edward R. Taylor, on "A Closed and Continuous Working Electric Furnace." The author points out that continuity of operation is very important, and almost an absolute necessity for most

chemical manufacturers. Movable electrodes in a closed electric furnace present serious difficulties in this regard. He early thought of using pieces of conductive material that can settle down upon each other from above, and properly arrange themselves and feed down by gravity. He decided to carry the current into the furnace by the use of a stationary conductor of moderate size, and to separately arrange the moving portions inside of the furnace itself. In his former paper, read at the Philadelphia meeting of the Society, he presented a plan of prolonging the life of the electrodes by regularly feeding upon them and at their ends, by gravity, broken conductive material. In his present paper he describes what is practically a continually self-renewing electrode in a closed furnace, the broken and moving portions in their continual descent themselves constituting the electrodes. New material constantly descends and takes the place of that exhausted at the ends of points of wear. The conduits through which these broken pieces are fed are suitably connected by an insulated conductor through the shell of the furnace to the source of electricity. Suitable hoppers are made above the conduits and outside of the furnace, through which the broken conductive material can be fed into, and ultimately through, the several conduits, at the bottom of which the broken fragments are free to arrange themselves by gravity, so that the weakest part of the circuit will be determined where the pieces come together at the bottom of the furnace. As fast as the lower ones are exhausted, others feed down from above and take their place. A second requisite for an electric furnace that shall be capable of continuous and prolonged use, without stopping to clean out, is that either a non-volatile product or residue may be removed from the furnace, either continuously or at intervals, in a fused or molten state. Provision is made to increase or reduce the resistance of the furnace at will by feeding conductive or non-conductive material through openings provided in front of the conduits down upon the working ends of the electrodes, so that comparatively quick changes can be made in the resistance of the working furnace. Mr. Taylor stated that, with less nerve on his part and less actual risk of failure than it required to build the furnaces he operates at present, he could now construct a continuous electric furnace that would dwarf the largest blast furnace in existence. (An illustrated description of the latest form of his furnace is given on another page of this issue. See also the notes on his latest patent in the Analysis of Current Electrochemical Patents.)

## THURSDAY'S SESSION.

The first paper of this session was on "Pumps and Other Accessories in Electrochemical Processes," by David H. Browne. In the absence of the author, it was read by W. McA. Johnson. A longer abstract of this paper is given on another page of this issue. It was discussed by Messrs. Keith, Hering, Johnson and Richards. Dr. Keith and Mr. Hering pointed out the advantages of the compressed-air lift system for such solutions, which is of special value when the aeration and resulting oxidation of the solution is desirable. Mr. Johnson said that steam injectors are suitable in some cases.

The next paper was on "Electrochemical Polarization," the author being Prof. J. W. Langley. In his absence, the paper was read by H. N. Potter. The author mentions Reed's definition of electrochemical polarization as a progressive change in the composition and e. m. f. of an electrochemical system necessitated by the progressive exhaustion of one or more of the electrochemical reagents. He takes exception to the importance given to the idea of progression as an essential part of the phenomenon. The phenomenon of polarization is generally considered to occur instantaneously upon the passage of a current through an electrolyte, and it usually reaches a limiting value very soon. The solution begins to be altered at the face of each electrode instantaneously, this change being always of such a character as to make the cell act as a primary battery, with its e. m. f. opposed to that of the e. m. f. which is driving the electrolyzing current. This is true even in the case of so-called non-polarizable electrodes; for instance, when a current is passed through a cell containing two zinc plates in zinc sulphates. He describes the following method for measuring the counter e. m. f. of polarization. A current is passed through an electrolytic cell, and by means of a quick acting commutator the feeding current is interrupted, and then, almost instantaneously, the electrodes are connected in series with a condenser. The circuit between the electrodes and the condenser is then broken, and the latter discharged through a ballistic galvanometer. The commutator is arranged to do all this by a single movement of the switch, and in a very brief interval of time. The observer thus obtains the voltage of the charging current, and about one-tenth of a second later the counter e. m. f., caused by the chemical products corresponding to polarization. He gives the results of a series of experiments in form of diagrams, in which the abscissas represent the applied volts of the electrolyzing current and the ordinates the polarization voltage. The experiments were made with various solutions, and also with fused salts. The general character of the curves is that, first, the polarization voltage rises with an increase of the charging voltage as a nearly linear function, later less rapidly, and finally reaches a constant value. This constant value apparently indicates that then the entire stratum on the face of the electrodes, and of the thickness of at least the radius of molecular attraction, is occupied solely by the chemical substance at that face, *e. g.*, for pure water a solution of oxygen at the anode and a solution of hydrogen at the cathode. Prior to this time the film is only partly composed of these substances, some of the original liquid still being present. The author is opposed to considering ohmic resistance as forming any part of electrochemical polarization. The method of discharge seems to be the only one, but, as the polarization should be regarded as the instantaneous value of the counter e. m. f. existing during the passage of the electrolyzing current, the above method, by discharge, will always give too low results, because there is a certain, although very small, time interval between cutting off the electrolyzing current and cutting in the condenser.

The paper was discussed by Messrs. Hering, Reed, Cowles, Potter and Richards, the principal point of discussion being the definition of polarization. Mr. Potter criticised the experimental method, as the existence of an indefinite time element introduces a doubt with respect to the experimental results.

The last paper of the session was on "Some Phenomena of Electrolytic Conduction," the author being C. J. Reed. As Mr. Reed, the very active secretary of the Society, was compelled to leave for home on that very morning, on account of sickness, his paper was read by Carl Hering. The author starts with some general remarks on oxidation and reduction as representing the true electrochemical action. He compares, with the aid of diagrams, two different views which are held on the details of the mechanism of the migration of the ions. He calls the one that of Faraday, and the other that of the dissociation theory. He then describes experiments which he has made, the principal one being as follows: A receptacle is divided into various compartments, filled with electrolytes, the end compartments containing the electrodes, so that all compartments are in series. For the sake of simplicity (although Mr. Reed's apparatus is more complicated), we may assume that there are three compartments in series, separated from one another by diaphragms. In the middle and cathode compartments we have a solution of sulphuric acid; in the anode compartment we have copper sulphate. The density and composition of the copper sulphate solution in the anode compartment are artificially held constant during the test. When a current is sent through this system it is easy to calculate what should happen if the whole process consisted in a traveling of H, Cu and $SO_4$ ions with their respective mobilities, which have been determined by previous investigators. As the H ions have a much

...ander and the $CO_3$ ions a smaller velocity than the $SO_4$ ions, ...simple calculation shows that one should expect that the ...ge of the solution of the middle compartment and the con... of $SO_4$ to the same should decrease. This was, however, ... the case in Mr. Reed's experiments. Just the opposite took place, and the volume of this compartment continually increased.

Although Mr. Reed had simply stated the fact and its disagreement with the simple calculation mentioned above, most of the speakers who discussed the paper appeared to regard it as intended to overthrow the electrolytic dissociation theory, and endeavored to show that the results of the experiments do not prove the incorrectness of this theory. Messrs. Hering, Potter, Cowles, Johnson and Richards participated in the discussion. Mr. Hering pointed out that Mr. Reed's experiment did really not represent a test of the dissociation theory, but was a sort of determination of the ionic velocities. In such a determination the nature of the porous diaphragms is of great importance. It was also pointed out that Mr. Reed did not take into account the phenomenon of electric endosmosis, which is known to exist. Mr. Potter expressed the opinion that Mr. Reed's apparatus was of such a construction as to necessarily introduce sources of error. He thought that heat affects may have been the cause of the increase of volume. Professor Richards thought that the use of the word "dissociation" for ions in solution is unfortunate, and explained the difference between chemical dissociation and electrolytic ionisation by means of mechanical analogies. Mr. Reed will certainly reply in the *Transactions* in a communicated discussion.

At the close of the session, Mr. Hering moved resolutions of thanks, for courtesies received, to the Local Entertainment Committee, the Ladies' Committee, the Niagara Power Co., the Niagara Falls Hydraulic and Mfg. Co., the National Food Co., the International Acheson Graphite Co., the Carborundum Co., the Electrical Lead Reduction Co. and the Atmospheric Products Co. The meeting then adjourned.

## PUMPS AND OTHER MECHANICAL ACCESSORIES IN ELECTROCHEMICAL PLANTS.

In an American Electrochemical Society paper, which is valuable on account of the large amount of technical information given in it concerning details, David H. Browne, Cleveland, Ohio, points out that the successful conduct of any electrochemical process depends to a large extent upon the practical solution of the mechanical problems involved. He gives in a humorous style a very interesting account of his struggles with pumps, heaters and other mechanical accessories, as he had to handle for several years a hot concentrated solution of chloride of copper and nickel, with some free chlorine, some hydrochloric acid, and a lot of impurities, such as sand, graphite, copper sulphide, metallic particles, chips of wood, etc.

First, he records a long series of unsuccessful trials with various arrangements, all of which had to be finally discarded; but when this paper will be printed in full, it will be interesting reading, because the author not only describes the unsuccessful arrangements, but also says why they were unsuccessful. When the problem of evaporating and concentrating large amounts of solution became important, they devised a concrete evaporating pan of the following construction. The base of this evaporator was built of brick, the top course being laid in cement, and a cement coat with a slight slope to the front being laid over the top of the brickwork. On this platform was built a shallow concrete pan with sloping sides; a wall down the middle divided this into two equal compartments, which communicated with an opening in the party-wall; they were covered by heavy tiles. While the solution is flowing through, any crystals settling out are raked off the bottom up the sloping sides to a trough. A chimney assists in drawing a current of hot air from the brick oven heated by an oil burner. While this apparatus was successful to some extent, there were two sources of trouble: the coating of the solutions with a floating layer of crystals, and the cracking of the concrete due to alternate heating and cooling. The trouble due to the coating of salts covering the surface of the liquid suggested to them an idea of an evaporator in which a very thin film of solution is continually exposed to a stream of hot air.

The apparatus consists of an iron shell, closed at the upper end by a circular lip, and at the lower end by a similar, but more shallow lip. This shell is lined with bricks and cement and is rotated by a peripheral driving gear. An oil burner in a brick furnace to one side produces a current of hot air, which entering the evaporator by a sleeve, passes along the top of the arch, meeting there a film of liquid which is continuously dragged up from the pool. The solution flows in continually and flows out continuously over the lip through a ring opening around the air sleeve. Any crystals separating are carried in suspension into a tank where they settle out, while the solution passes on towards the pump pit. At first they used a fan to draw the air through, but they found out that better results were obtained by checking the air flow to such an extent that the exit gases were nearly saturated with moisture. He recommends this apparatus as very satisfactory; for further details and illustrations we must refer the reader to the full paper.

When a pump is made of parts—generally three main parts—he recommends to assemble the three main parts in a box, laying the pieces close together without gaskets between. Around these pieces granite concrete is rammed, and the block allowed three or four days to harden before removing the box. To provide for the bolts which hold down the valve checks and the piston gland, short pieces of iron pipe may be laid in the box before the concrete is rammed in, or still better, T-shaped slots may be provided in the concrete by suitable wooden forms nailed against the side of the mould. A three-piece pump so mounted is practically one solid block of stone. It requires no fastening, can be laid on the floor anywhere, and is very readily lined up beneath a driving shaft. As a gasket for this style of pump he has found common felt well soaked in P. & B. paint to be a good substitute for hard rubber.

Recently, they also used pumps made in one piece. Such a pump is very easily mounted in a concrete block. One end is provided with a skeleton ball check, which acts both as a check and discharge opening. The exit pipe is coupled to this by a flat flange and hard rubber nipple. To hold down the check and the piston gland they use a heavy cast-iron plate with two claws on each side, against which the bolt heads or washers can be drawn up. This makes a very compact form of pump mounting.

As a suction pipe he uses either a section of a wood pump log drawn tight against the lower part of the pump body, or a hard rubber flange and nipple coupled to a length of flexible hose of sufficient wall thickness to withstand the collapsing strain. For discharge pipe he uses almost exclusively a permanent concrete main.

## ELECTROCHEMICAL LECTURES.

**Franklin Institute.**—Among the papers announced on the preliminary programme of the sections of the Franklin Institute of Philadelphia we note the following: Dr. J. W. Richards, Bethlehem, and C. M. Hall, Niagara Falls, "The Electrothermic Production of Aluminum from Bauxite;" Dr. Harry F. Keller, Philadelphia, "The Synthetic Production of Perfumes and Flavoring Matter;" W. E. Ridenour, Philadelphia, "The Influence of Bleaching Agents on the Tensile Strength of Textile Fibres;" Miss A. L. Turner, Philadelphia, "The Electrolysis of Di-sodium Phosphate;" A. C. Johnston, Philadelphia, "Ore Handling;" Dr. H. C. Jones, Baltimore, "What Physical Chemistry Has Done for Chemistry."

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl.

### Electric Furnaces and Furnace Products.

*Reduction of Metals from their Ores, etc., in Electrically-heated Furnaces.* Ramon Chavarria Contardo, Sevres, France. Patent No. 706,651, July 29, 1902.

This invention, according to the specification, "relates to a process and apparatus for the production of metals directly from their ores, and more particularly to a process for producing cast iron or steel of any desired degree of hardness directly from iron ore without the use of solid fuel." For this purpose the inventor, who is a doctor of laws, a citizen of the Republic of Chile and residing in Sevres, France, constructs a furnace, very much like a blast furnace in cross section, in which he proposes to furnish the heat necessary for the melting of the charge by means of the electric arc. This heat is to act only by convection and radiation, as the material itself does not come into contact with the arc, the electrodes being carefully protected by shields. To accomplish the reduction of the heated ores he proposes to introduce into the bottom of the furnace, below the electrodes, a current of dry hydrogen or carbon monoxide, obtained from a suitable generator. He also states that in the particular case where the furnace is to be used for the production of cast iron or steel, it is necessary that carbon combine with the iron and that this may be attained by introducing into the reducing-gas current an easily proportionable quantity of a hydrocarbon in the form of gas or vapor, by which procedure it is claimed that the exact quantity of carbon required can be combined with the iron. From the above description it can already be inferred that the process in question appears to be one of the many which have been proposed for the utilization of the electric current in the metallurgy of iron, but which have never been heard of in practice. Besides using a temperature much beyond anything required in the iron business, the process presents metallurgical and practical difficulties which are almost or quite unsurmountable. There is certainly no need of apprehension on the part of stockholders of iron and steel companies, as long as such complicated and expensive processes are proposed to take the place of the simple and well-developed processes used at present in the metallurgy of iron. The problem seems to be an attractive one to inventors, especially those who are not metallurgists by profession, although there is probably less chance for electricity to be applied in the manufacture of iron and steel than in that of any of the other metals.

*Electric Furnaces.* Arthur Parker, Chorley, England. Patent No. 706,099, August 5, 1902.

The inventor describes a new form of carbide furnace, designed, according to him, to secure a more complete, perfect and continuous fusion of the raw material. The furnace is a crucible furnace, lined perfectly with carbon, and so arranged that it can be slowly rotated around its vertical axis. The carbon electrode is as usually arranged in such a manner that it can be moved upwards as the melted charge fills the crucible. The main characteristic of the furnace seems to consist in the shape of the carbon electrode employed, which is described as being oblong in cross-section, either rectangular or oval. As the furnace is rotated, each part of the charge comes successively within the range of the electric arc, over and over again. The inventor lays special stress on the fact that the arc is not struck between the electrode and the crucible through the material, but between the electrode and the melted carbide, and that, therefore, the carbon electrode does not come into contact with the material through it the whole operation. The material to be fused is delivered into the crucible in a thin stream on both sides of the oblong carbon electrode through hoppers and tubes composed of an insulating material, and it is intended to have it fall down through the arc and thus become fused before reaching the bottom of the crucible.

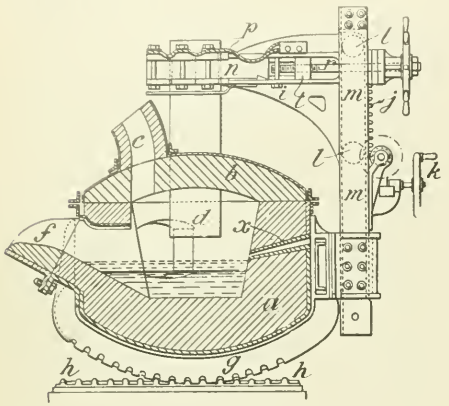
*Electric Furnace.* Edward R. Taylor, Penn Yan, New York. Patent No. 706,128, August 5, 1902.

This furnace embodies various improvements on the inventor's previous furnace, and is to be used primarily for the production of carbon bisulphide, though according to the specification it may be used for other reductions and reactions. Mr. Taylor has had an experience of many years in the manufacture of carbon bisulphide, and deserves great credit for the successful application of electricity in a case where the existing methods were of a most unsatisfactory character. The furnace described in the present patent is used by him on a large scale at Penn Yan, New York. The construction shows a central shaft, through which the charcoal or coke is delivered into a larger working chamber. Concentric to this shaft is arranged a circular space for the feeding in of the sulphur, while several more concentric passages, serving the same purpose, are arranged around the working chamber. The object of this construction is to utilize the heat generated in the working chamber also for the heating and melting of the sulphur, which is delivered by the various passages at different levels in the working chamber. By this means the sulphur is brought into contact with the carbon at a number of places, and the best possible conditions for the reaction are realized. The current is introduced into the furnace by four electrodes, 90° apart, which are constructed in the form of a metallic trough, lined with carbon bricks on three sides and covered with a non-conducting cover on the side towards the interior of the furnace, which arrangement prevents the current from passing directly from one electrode to the other in the upper part of the furnace. These electrode troughs serve at the same time as passageways for the granular conductive material, which is fed into them continuously, and which, after leaving the electrodes, spreads itself out on the bottom of the working chamber and is there heated by the current to the proper temperature. For the protection of these passageways and the regulation and control of the operation of the furnace there are arranged passages running above and parallel to them, by which either conductive or non-conductive material can be introduced into the working chamber and can thus be brought right in front of any or all of the electrodes. The specification is one which will recommend itself to any practical man for the clear statements it contains, which are all to the point and bear witness that the apparatus it describes is a product evolved from actual practical conditions. It shows in this respect a marked contrast to many others, which are unhappily too full of glittering generalities in which the respective inventors allow their fancy to run riot.

*Oscillating Electric Furnace.* Paul L. Héroult, La Praz, France, assignor to Société Electro-Metallurgique Française. Patent No. 707,776, August 26, 1902.

Héroult, the well-known electro-metallurgist and inventor of the Héroult aluminum furnace, describes in this specification the construction of an oscillating electric furnace, which is to be used among other purposes for the manufacture of steel. As shown in the adjoining diagram, the furnace consists of a crucible *a*, provided with a cover *b*, a small chimney *c*, and a spout for running off the metal on tilting the furnace. The bottom of the furnace is arched and cogs on rails engaging with cogs on rails *h* are arranged for effecting the tilting. The carbon electrodes *d*, surrounded by a collar *n* of sheet

which the copper wedges serving to convey the current from the cables *p* to the electrodes, are carried by arms *i* projecting from sliding uprights *j*. The uprights *j* are guided by rollers *l* in a standard *m* of trough-shaped section, and can be worked by a worm and hand wheel *k*. A screw spindle *r* and nut *t*, turned by a hand wheel, provides for the tightening and loosening of the collar *n*. In order to use the

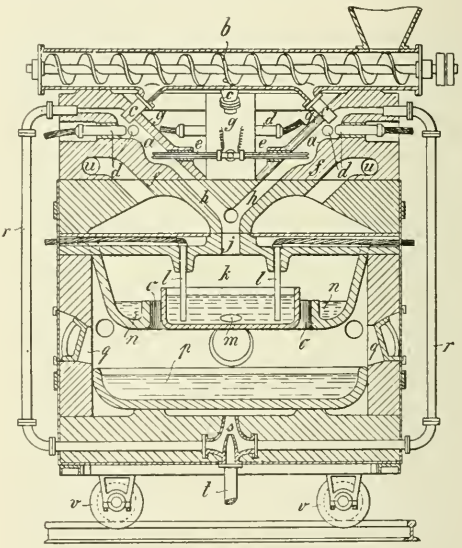


HEROULT FURNACE.

furnace for bessemerizing, a wind chest is arranged at the back of the furnace, from which tuyeres *x* lead into the working chamber. The tuyeres open ordinarily above the level of the bath, but are submerged when the furnace is tilted back in order to carry out the Bessemer process. Though anything coming from Héroult is entitled to serious consideration, it seems that the use of electric furnace in a process which has been brought to such perfection in the working and handling of enormous outputs as bessemerizing has been is an undertaking which will have to contend with many difficulties. It is proposed to use a pig iron, which, as the specification says, "need not contain either phosphorus or silicon," which probably means pig iron low in phosphorus and silicon, as it would be impossible to find a pig iron in the market which does not contain either of these elements. Such pig iron can be used, as it is not necessary in the electric furnace to depend on the oxidation of the silicon in the acid converter or the phosphorus in the basic converter in order to furnish the necessary heat for the process, which heat is, in this case, supplied by electricity. Pig iron of this kind could, of course, be obtained at a lower price than that used ordinarily in bessemerizing, but this difference would hardly be sufficient to make up for the increase in cost due to the use of electricity. The last judgment in this case will have to be pronounced before the tribunal of practice.

*Electric Glass Furnace.* August Voelker, Cologne, Germany. Patent No. 705,283, August 5, 1902.

Within the last few years several furnace constructions have been patented in different countries, having for their object the utilization of the electric current in the manufacture of glass. The name of the inventor of the furnace under consideration has already appeared in the patent literature in this connection, and the furnace is evidently an improvement on his earlier constructions. The apparatus as shown in cross-section by the adjoining figure, shows a worm conveyor *b*, by which the materials for forming the glass are delivered to four tubes *c*, which lead into inclined radial passages *h* over what the inventor calls the "hearth" *a*. These passages are formed by four refractory blocks *f* and are covered by slabs *g*. There the material is melted by the heat of arcs between the electrodes *d* and by arcs of so-called jablochkoff candles *e*. The material flows down through the passage *j* into the refining vessel *k*, where the melt is kept fluid by the introduction of another alternating or direct current by means of the electrodes *l*. Here the principle of resistance heating is employed. From *k* the melt flows by openings *m* into the circular trough *n*, whence it overflows by the passages *o* into the lower vessel *p*, where it is worked by tools through the working doors *q*. The vessel *p* is heated by the burning under it of the combustible gases which are evolved in the passages *h*, and are conducted under it by the pipes *r*. The burning is effected by a suitable burner *s* provided with an air-pipe *t*. The apparatus is mounted on wheels *v*. *U*, *u* are channels through which such incombustible gases as are evolved pass off.



VOELKER GLASS FURNACE.

The furnace under consideration removes one objection which has been urged against several other constructions, namely, that no provision was made for a thorough liquation of the glass after melting, which is just as important for getting a good product as the melting itself. This, as it appears, has been amply considered by the inventor. There may be a question whether the use of a separate electric current for keeping the melt liquid will pay in practice; in all cases it seems that a direct current would be objectionable if the inventor should have intended to avoid all danger of possible electrolytic effects. It is also difficult to see how the serious objection arising from the contamination of the melt by carbon dust or carbon particles falling down from the electrodes can be overcome in a satisfactory manner.

*Manufacture of Glass by Means of Electricity.* Yegor Broom, Cologne, Germany. Patent No. 708,309, September 2, 1902.

The present furnace is designed, according to the inventor, to overcome the difficulty which is encountered in previous constructions in that the mixture became agglomerated by partial fusion before it reached the electrodes. In consequence of this it had to be pushed forward, thus arriving at the electrodes intermittently, and not only subjecting them to variable strains, but causing much carbon dust to fall into the glass melt and contaminate it. The inventor proposes to overcome these difficulties by using the mixture in the shape of compressed balls, etc., or of a continuous moving rod. He

arranges a mixing apparatus where he mixes the raw material with a suitable binding material, then it is passed through one pair of rollers where it is compressed and a second pair of heated rollers where it is dried. From there the material passes in a continuous-moving strip between or beneath the electrodes of the furnace, where it is melted by the heat of the electric arc. It would seem from this construction that there still exists an opportunity in this apparatus for the melt to become contaminated by particles falling into it from the electrodes. The construction is open to objection for the reason mentioned above, namely, that no provision apparently is made for the liquation of the glass melt, unless it is intended to perform that process in another apparatus heated by ordinary means. The patent is assigned to the Gesellschaft zur Verwerthung der Patente für Glaserzeugung auf electrischen Wege, Becker & Co., Cologne, Germany, who own several other electric glass processes.

### Apparatus and Processes for the Electrolytic Production of Metals and Compounds.

*Process of Manufacturing Manure from Apatite or Similar Mineral Phosphate.* Johan Gustav Wiborgh and Wilhelm Palmaer, Stockholm, Sweden. Patent No. 707,886, August 26, 1902.

The process as described aims at the formation of an easily-soluble phosphate from apatite or other hard soluble mineral phosphates by electrolysis. For this purpose the inventors use as electrolyte a salt which, on electrolysis, furnishes at the anode an acid capable of forming a soluble salt with lime and at the cathode a basic hydrate. As electrolyte they prefer alkaline or ammoniacal salts which contain, for instance, nitric acid, chloric acid or perchloric acid. The mineral phosphate is placed "in a suitable manner" near the anode and the acid liberated there is supposed to dissolve it. When this solution comes into contact with the cathode liquid, where the alkaline hydrate has been formed, the dissolved phosphate of calcium is again precipitated, but this time in another form, as a white flocculent precipitate which is easily soluble in citric acid. It is said to be advantageous to use a porous diaphragm, so as to prevent the precipitate from going over towards the anode and being redissolved. It is claimed that the electrolyte remains nearly unaltered, but as that is usually claimed by all inventors and so rarely found true after a process is introduced into practice, and as no reactions are given to support that assertion, the statement will have to be verified by actual demonstration. That complex salts like the chlorates or perchlorates should be so easily reformed is somewhat hard to believe. If the salts should not be reformed, then the use of high priced electrolytes for the manufacture of a cheap product will naturally be inadmissible. The question of apparatus is, of course, not considered in this spirit, which is a process patent only, but it would be interesting to know in what manner the inventors have succeeded in overcoming the difficulties about placing the material "in a suitable manner" near the anode, so that the anion will act on it. This alone has been the stumbling block of a good many processes already. It seems also that the cost of power would be very high as compared with the price of the product, as the resistance of the bath will undoubtedly be great, due to the fact that a diaphragm will have to be used and that the anode has to be practically surrounded by a non-conducting substance, to wit, the material to be acted upon

*Apparatus for the Electrolytical Treatment of Ores or Slimes* Frank T. Mumford, Kalgoorlie, Western Australia, Australia. Patent No. 706,436, August 5, 1902.

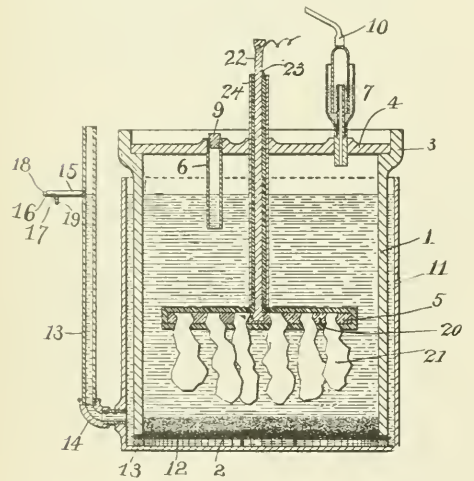
The invention, according to the specification, relates to an apparatus for the treatment by electrolysis of ores and slimes for the extraction of precious metals, particularly gold, therefrom, whereby the solution of the precious metals from the ore and its deposition are effected by the aid of mercury in an easily recoverable condition. The apparatus is said to be applicable for the treatment of any auriferous ore, but to be especially valuable in the case of a slimy and clay-like ore which requires very fine crushing. The apparatus consists of a steel cylinder lined on the inside with amalgamated sheet copper, and having at the bottom a layer of mercury. This cylindrical shell forms the cathode of the apparatus, while the anodes are formed by a number of carbon or iron rods, passing insulated through the closed ends of the cylinder and running parallel to the sides. The cylinder can be rotated about its horizontal axis. As electrolyte is claimed a solution of cyanide of potassium or sodium, chloride or bromide of sodium or other suitable salts, either jointly or separately. The operation is described as follows: The cylinder is filled with the crushed ore and electrolyte, and started to revolve slowly. The current is then introduced, which is expected to dissolve the gold by means of the anion liberated and deposit it as amalgam on the cathode. Any coarse particles of gold in the ore are supposed to be immediately amalgamated by contact with the mercury. At the end of the operation the mercury is run off, the amalgam squeezed out and retorted. The process, on reading the specification, appears to be as easy, as is termed in the common vernacular, as rolling off a log. One fills the gold ore and electrolyte into the cylinder, turns on the electricity, turns the crank, as it were, and finds the gold at the end in the mercury. But when one recalls the legions of apparatus of similar construction which have been patented for the same purpose and have died a peaceful death in the archives of the Patent Office, one cannot help but feel a little skeptical about the practical success of this one.

*Electrochemical Apparatus.* Chauncey C Clark Philadelphia, Pa. Patent No. 706,520, August 12, 1902.

The object of this invention is to construct a closed apparatus for the electrolysis of chemical solutions, as the production of bleach liquors by the release of chlorine from common salt, the electrodes and their connections being kept at a low temperature. It is said that in consequence of the low temperature the electrical resistance of the electrodes is so largely diminished that the life of the electrodes and their connections is greatly prolonged. The apparatus consists of two copper or iron cylinders, one within the other, so that the inner one is completely surrounded by cooling liquid. In addition to that the inner cylinder is traversed lengthwise by copper tubes, arranged similar to the tubes in a tubular boiler, which tubes serve also for the circulation of cooling liquid. The electrodes are screwed to bars running the whole length of the inner cylinder, parallel to the tubes and the electrode material is platinum for the anodes and zinc for the cathodes. The cooling fluids enumerated are "liquid air, ice water, compressed air or other suitable or available cooling fluid or material." This is the gist of the invention, but enough will be gathered from this to show that the inventor has upset all our ideas about the electrolytic production of bleaching liquors and the chemical action of the product obtained thereby. Up to now we had supposed that free hypochlorous acid, which, according to Foerster and Bischoff's researches, exists in bleaching solutions prepared by electrolysis and to which their strong bleaching action is due, would energetically attack metals like zinc and copper and destroy them in a very short time. Preceding inventors in that line had proposed various apparatus and had to cool their solutions in order to prevent the formation of chlorate, though they could not afford to use liquid air or ice water. Then a high current density and reversible electrodes as in the well-known Kellner apparatus were supposed to be absolutely necessary. Furthermore, it was thought that sheets of platinum of sufficient strength to resist for any length of time as electrodes were prohibitive as far as their cost was concerned, a reason why Oettel used carbon electrodes in his apparatus. An active circulation of the electrolyte was also considered necessary. This is all done away with in the apparatus under consideration. It would perhaps be interesting to look into it after a current of say 200 amperes has been going through it for half a day and see what happened.

*Electrolytic Cell.* Adolph Sommer, Cambridge, Mass. Patent No. 707,804. August 26, 1902.

The specification describes a new form of an electrolytic diaphragm cell, which is reproduced in the adjoining figure. The cell consists of an iron tank 11, which forms the outer part of the cell and serves as cathode at the same time. In it is placed a stone or earthenware tube 1, having a flange 3 in which is secured a cover 4, with water-seal tube 7 and replenishing tube 6 closed by cork 9. Through the center of the cover there enters the anode 5, consisting of a metallic base 20, in which a plurality of pieces of carbon 21 or other suitable substance are embedded. A rod 22 is in connection with the metallic base, which rod is covered by a coating of asphaltum or other suitable material 23 and a sleeve 24 of glass, etc., serving to protect the covering. The anode is somewhat smaller than tube 1, allowing space for gas and liquid to pass between. Between the lower end of tube 1 and the bottom of tank 11 are interposed in the order named a sheet of non-fibrous foraminous material 12 and a support 13 of some non-conducting material, as glass, porcelain or stoneware. Upon the sheet 12 and inside of tube 1 is placed a layer of granular material,




SOMMER ELECTROLYTIC CELL.

as crushed glass or quartz sand, just crushed large enough so as not to pass through the meshes of the non-fibrous foraminous sheet. 13 is a discharge pipe with elbow 14 and several small branches 15, 16, 17, 18, 19. The advantages claimed for this apparatus are: First, the tubular anode compartment, making it possible to remove the cover and gain access to the anode very quickly; second, the iron tank which constitutes the cathode; third, the peculiar construction of the diaphragm, which is made of a sheet of foraminous non-fibrous material having small openings and a layer of granular material which lies on the sheet and closes the openings.

### Improvements in Storage-Battery Construction.

*Separator for Electric Accumulator Plates.* Richard A. Katz, Berlin, Germany. Patent No. 705,630, July 29, 1902.

This invention provides a separator for electric accumulator plates of non-conducting material, consisting of a combination of two wide meshed gratings, of which the intersections of the one cross the open spaces of the other. Thus ample space for passage of the electrolyte is assured and the plates are supported at the same time along numerous uninterrupted lines.

*Composition for Use in Secondary Batteries.* Carl Oppermann, London, England. Patent No. 706,444, August 5, 1902.

The object of the invention is to render the active material harder and less liable to disintegration, which the inventor proposes to do by making up the lead oxide into a paste with diluted sulphuric acid and adding a solution of Trinidad asphaltum, preferably dissolved in benzine and diluted with alcohol. After applying the paste to the support he dries it at a low temperature to drive off the solvent of the asphaltum, and claims that this acts as a cement and increases the hardness of the active material.

*Electrode for Storage Batteries.* Charles W. Kennedy, Rutledge, Pa. Patent No. 706,568, August 12, 1902.

The object of the invention is to provide an electrode with a maximum amount of active surface and a minimum amount of weight, which he attains by a peculiar mechanical construction which is described at length in the patent.

*Electrode for Storage Batteries.* Henry Woodward, London, England. Patent No. 707,666, August 26, 1902.

The invention consists in a construction designed to reduce the weight of storage batteries and at the same time to provide better means for retaining the oxide of lead upon the positive and negative plates. The inventor forms the positive plate of his accumulator from thin strips or tapes of lead and claims "an accumulator plate comprising a plurality of strips crossing each other and pivotally connected together to permit expansion and contraction."

### Galvanic Cells.

*Galvanic Battery.* Charles S. Schoenmehl, Waterbury, Conn. Patent No. 705,616, July 29, 1902.

This concerns an improved form of copper oxide cell designed for use in automobiles, etc., in which the electrodes are kept rigid by suitable mechanical means, which allows the use of the cell in any place where it would be subject to rough handling and shaking.

*Electric Battery.* Edward R. Gill, New York, N. Y. Patent No. 705,919, July 29, 1902.

This patent embodies various mechanical features which aim to facilitate the connection of cells in series and the removal of any of them without disturbing the circuit. It is, as the inventor describes it, an improved form of socket whereby cells made in accordance with his invention are quickly and easily put into or out of circuit without interfering with the operation of the battery.

*Battery.* William L. Panikoff, New Haven, Conn. Patent No. 706,340, August 5, 1902.

The specification says: "This invention relates to batteries, and more particularly to that class of batteries in which it is desired to use different strengths of current, and has for its object the construction of a device by which a series of batteries are adapted to be used singly or in series according to the wish of the operator, and that when not in use the plates of the batteries may be held in position free from the flint contained in the jars themselves." A mechanical construction for this purpose is described in detail.

*Electrochemical Generator.* Harry S. Amwake, Camden, N. J. Patent No. 12,019, reissue, August 12, 1902.

The inventor proposes to construct a cell "in which the chemical action shall not markedly exceed the rate at which the electric current is drawn from the cell," and also to "secure a cell giving a high and constant electro-motive force." For this purpose he arranges a current-conducting baffle plate or partition between the electrodes, and claims that "thereby the movement of the electrolyte, due to differences of temperatures between different parts of the same, will take place in a devious or circuitous path, whereas the electric current may pass directly through the conducting baffle from one electrode to the other."

*Chemical Generator of Electricity.* Edward Lacey Anderson, St. Louis, Mo. Patent No. 706,631, August 12, 1902.

The invention consists of a cell with an aluminum and a carbon electrode, and an electrolyte composed of a suitable halogen salt or salts, *i. e.*, a fluoride or chloride, or both—an acid and preferably in practice a depolarizing agent.

*Galvanic Battery.* Eason L. Slocum, Pawtucket, R. I. Patent No. 707,363, August 19, 1902.

The cell is designed to furnish a current either of quantity or intensity, as the inventor provides a containing jar which has five separate positive electrodes and also the negative electrodes made in divisions.

*Electrochemical Generator.* Harry S. Amwake, Camden, N. J. Patent No. 707,372, August 19, 1902.

This is an improvement on the cell described above and consists in using a baffle plate in connection with both the negative and positive electrode, that is to say, in using one baffle to surround the positive electrode or electrodes, and another baffle to surround the negative electrode or electrodes.

*Electric Battery.* Ernest A. G. Street, Paris, France. Patent No. 707,731, August 26, 1902.

The invention provides a detachable vessel to be connected to the electrode of a galvanic cell, which vessel contains the depolarizing agent. By the construction shown in the specification it is possible to renew the depolarizing agent quickly without interfering with the electrode.

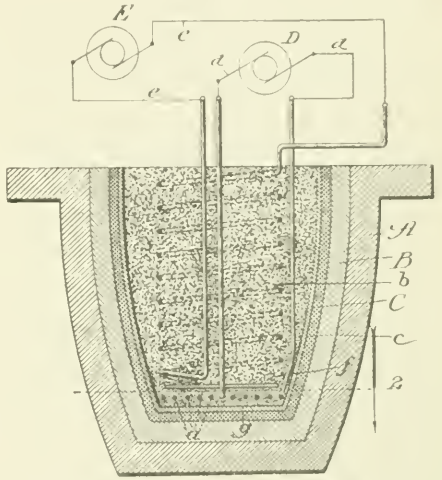
### Miscellaneous.

*Method of Electrodepositing Metal on Lace.* John Andrew Daly, Washington, D. C. Patent No. 707,306, August 19, 1902.

The inventor takes the articles of lace or other flexible material on which he wants to get a metallic deposit and prepares them in the usual manner by coating their surface with an electrical conductor, either by rubbing graphite on them or in another suitable way. He then lays them on a wire basket and winds a number of turns of fine wire around them and the basket. Thereby he brings the articles into contact with the wire and the basket at a great many places and as soon as the basket is made cathode in an electrolytic bath, the deposit starts right away at the contact points and from there spreads over the articles to be coated. He does not allow the current to act more than a few minutes, or just sufficient to give stiffness to the articles, because they would stick to the wire if left too long and would thus be spoiled. After they have been stiffened in this way they may be suspended into the electroplating bath by metallic hooks, and the deposit of metal may then be continued.

*Method of Treating Metallic Oxides in the Production of Metals and Alloys.* Frederic C. Weber, Chicago, Ill. Patent No. 705,727, July 29, 1902.

This invention is claimed to be an improvement in the process of producing metals by reduction of their oxides by means of metallic aluminum. In the Goldschmidt process, introduced into practice by the Allgemeine Thermit Gesellschaft, of Essen, Germany, this reduction is accomplished by mixing finely-divided aluminum with the metallic oxide to be reduced and starting the reduction at one point by igniting a strip of magnesium wire inserted into a cartridge filled with an easily reducible oxide, such as peroxide of barium. The easily reducible oxide is reduced by the magnesium and the heat propagates itself through the entire mass. It is claimed by the inventor of the process under consideration that various disadvantages, such as explosions, contamination of the reduced metal by magnesia, etc., can be avoided by using his method. The arrangement of the apparatus is as follows: *A* represents the outer vessel; *B* the lining of lime or graphite; *C* a lining of mineral wool and magnesia; *D* and *E* two sources of electrical energy. *a* is a coil of small aluminum wire placed in the bottom of the crucible. *b* is a helix of aluminum wire placed within the vessel above the coil, *c* a thimble of aluminum, *g* is finely powdered oxide, *h* is the coarser oxide which is to be treated and *f* is a sheet of tissue paper to prevent the mixing of the fine and coarsely powdered oxide. The process is started by heating the larger coil by means of a current to such a temperature below the melting point of aluminum as to drive all the moisture and water of combustion off. After this a current of sufficient intensity to melt the small




WEBER APPARATUS FOR REDUCING OXIDES.

aluminum coil in the bottom is turned on, with the result that the reaction starts there and propagates itself through the whole charge, producing a molten corundum slag and the desired metal.

## THE CONDUCTIVITY AND FREEZING POINTS OF AQUEOUS SOLUTIONS OF CERTAIN METALLIC SALTS OF TARTARIC, MALIC AND SUCCINIC ACIDS.*

By Prof. O. F. Tower.

In an article which appeared recently in the *Journal of the American Chemical Society* it was shown that the molecular conductivities of nickel and cobalt tartrates in aqueous solution were abnormally small, and also that the freezing-point method yielded apparent molecular weights considerably greater than those calculated from the simple formulas. The explanation was offered at that time that this behavior might be due to polymerization of the molecules. The object of this paper is to see if this behavior is confined to the tartrates alone of nickel and cobalt, and also to see if the nickel and cobalt salts of certain other acids are related to the tartrates. The determinations with nickel and cobalt tartrates have been repeated and determinations have also been made with magnesium, barium and manganese tartrates (these were the only ones of this class found to be sufficiently soluble), and nickel, cobalt and magnesium malates and succinates. The molecular conductivities of these salts at dilutions of 32 and 1,024 liters follow:

MOLECULAR CONDUCTIVITY.

| v | Tartrates | | | Malates | | | Succinates | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ni | Co | Mg | Ni | Co | Mg | Ni | Co | Mg |
| 32 | 10.1 | 15.5 | [illegible] | 58 | 57 | 61 | [illegible] | [illegible] | [illegible] |
| 1,024 | 90 | 115 | [illegible] | 72 | [illegible] | 87 | [illegible] | [illegible] | [illegible] |

The molecular weights calculated from the simplest formula for the respective salts, together with the molecular weights

* Abstract of a paper read at the Pittsburg meeting of the Amer. Chem. Soc'y, July, 1902.

found by the freezing-point method for a dilution of 16 and 32 liters, is given in the following table:

| | *Tartrates* | | | *Malates* | | | *Succinates* | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ni | Co | Mg | Ni | Co | Mg | Ni | Co | Mg |
| Mol. Wt. from formula | 207 | 207 | 172 | 191 | 191 | 150 | 175 | 175 | 140 |
| Mol. Wt freezing point { V = 16 | 236 | 244 | 122 | 164 | 179 | 120 | 168 | 111 | 82 |
| { V = 32 | 196 | 207 | 169 | 140 | 150 | 100 | 160 | 163 | 77 |

In addition to the tartrates of nickel and cobalt, the malates of these same metals show similarly low conductivities and high molecular weights. The succinates of nickel and cobalt act normally, as do the various other tartrates, malates and succinates investigated. These results seem to show that the presence of the hydroxyl groups in the tartaric and malic acids have some effect in causing this peculiar behavior of the nickel and cobalt salts. And the fact that the molecular weights found for the malates seem to indicate that the polymerizing effect increases with increase in hydroxyl groups.

However, after the above work had been finished, similar determinations were made with the nickel, cobalt and magnesium salts of malonic and tartronic acids to see if this would throw any light on the influence of the hydroxyl groups. Tartronic acid is related to malonic acid as malic is related to succinic acid, it was, therefore, to be expected that if the presence of the hydroxyl group tends to cause polymerization of the nickel and cobalt salts, the molecular conductivities of the tartronates of these metals would be considerably less than the molecular conductivities of their malonates, and that the freezing-point method would yield greater molecular weights in the former case than in the latter. The results obtained did not confirm this conclusion.

Although the nickel and cobalt salts possess lower molecular conductivities and higher apparent molecular weights than the magnesium salts, yet the results with the tartronates do not differ materially from those with the malonates. The hydroxyl group, therefore, does not seem to be the determining influence in the peculiar behavior of these nickel and cobalt salts. Just what causes this exceptional behavior of nickel and cobalt tartrates and malates must be left undecided. But there is undoubtedly something in the nature of the nickel and cobalt themselves which causes aqueous solutions of their organic salts in general to offer greater resistance to the electric current than similar salts of the other metals investigated, for example magnesium.

## TESTING CARBON ELECTRODES.

The following is an abstract of a paper read at the Niagara Falls meeting of the American Electrochemical Society, by Francis A. J. Fitzgerald:

In both electrochemical and electrometallurgical processes in which carbon electrodes are used the determination of their density is important. The general efficiency of the electrodes depends on the nature of the carbon and on the methods used in their manufacture, and much may be learned on these points by a determination of the density. Two different densities are to be distinguished; the real density and the apparent density. The apparent density is equal to the weight divided by the volume as a whole. From these two we get the porosity which

$$\text{is equal to the } \frac{\text{real density—apparent density.}}{\text{real density.}}$$

The determination of the *real density* is difficult on account of the persistence with which amorphous carbon and graphite retain air.

The apparatus used in this determination are as follows: a volumeter graduated to 100 c. c. in divisions of 0.2 c. c., and fitted with a rubber stopper through which passes a glass tube, the end of the glass tube inside the volumeter being drawn to a point and bent back; a water bath in which the volumeter is placed to keep the temperature constant; a vacuum pump; kerosene oil, such as "Acme Crown" kerosene, which has a high flashing point and is free from the volatile paraffine. Oil is used in the volumeter because it will not readily wet carbon.

The method of determination is as follows: A specimen of the carbon or graphite to be tested, weighing at least 30 grains, is cut from the electrode and weighed. The volumeter is partly filled with kerosene and is placed in the water bath. A reading of the volumeter is then taken, the specimen introduced and the instrument connected with the vacuum pump. When the pump gauge has shown the maximum attainable vacuum for a period of about ten minutes, the volumeter is disconnected and a second reading taken. The operation is then repeated and another reading taken. This method is followed until two consecutive readings are the same. The difference between the last reading and the original reading is the real volume, and from this the real density can be calculated.

There is no evaporation of oil, but in the beginning a serious loss of weight was found, which was due to the drawing off of a fine spray caused by the bursting of air bubbles at the surface of the oil. This difficulty was overcome by drawing out the glass tube and bending it back on itself.

The pressure is reduced to about 20 mm. of mercury by a filter pump. There is no constant error in the observations due to this imperfect vacuum.

In a determination by this method and by the specific gravity method, the following results were obtained:

Density determined by volumeter..... 2.1887
Density determined by specific gravity..... 2.1930

The *apparent density* is determined by giving the electrode a light coat of shellac, putting it into a volumeter which contains water, and then observing the volume of water displaced by the electrode.

The second part of the paper deals with the detection of amorphous carbon and graphite in carbon and graphite used as electrodes. Graphite shows greater resistance to oxidizing and disintegrating actions than any other form of carbon. To obtain the best results in electrolytic and electrometallurgical work the electrode should contain no amorphous carbon, and it is important to have some method of testing whereby amorphous carbon can be detected. The following is a method suggested by Berthelot: About 0.5 gram of the finely powdered electrode is introduced into a test tube containing 10 c. c. of nitric acid, and to this is added cautiously 4 grams of potassium chlorate. The test tube is then placed in a water bath and kept at a temperature of 60°, until all action is over, that is, for about ten or twelve hours. The nitric acid is then poured off, the residue is thoroughly washed with hot water by decantation and dried. By repeatedly treating the specimen in this way all the amorphous carbon present is converted into a yellowish-brown soluble substance, while the graphite yields a yellow insoluble substance, which has been named graphitic oxide by Berthelot. When a mixture of graphite and amorphous carbon is under observation the presence of the latter is easily recognized by the reddish-brown color of the water used in washing the oxidized products.

In the Acheson graphite electrode there is an entire absence of amorphous carbon, the electrode consisting wholly of graphite.

When it is desired to test an electrode to determine whether it is composed wholly of amorphous carbon or contains a certain amount of graphite a method of Staudenmaier may be used. The specimen to be tested is treated once with the oxidizing mixture, washed, heated in the water bath with a solution of potassium permanganate and sulphuric acid, and finally treated with an excess of hydrogen peroxide. If the specimen consisted wholly of amorphous carbon, a clear solution of a reddish-brown color is obtained, but if any graphite is present there remains an insoluble residue of a yellow or greenish-yellow color.

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

By Carl Hering.

## INDUSTRIAL ELECTROCHEMISTRY.

*Copper Refining.*—The long series of articles by Philip, of which the first parts were noticed in the synopsis last month, have now been concluded in the Lond. *Elec.*, August 15th, 22d and September 26th. The whole serial is to be published in book form, the portions published in advance being merely portions of this book. The concluding parts are limited to copper refining. Continuing his analysis of the costs he finds that the cost in dollars of dynamos and switchboard, including erection, is 0.28 T D, in which T is the output in tons per year and D the current density used in ampères per square foot. The cost of electrolytic vats is 60 T / D. The cost of the electrolyte required is 0.30 T S / D, in which S is the price of copper sulphate crystals per ton in dollars. The cost of the copper anodes is A T P / D, the thickness of the anode plates in inches being A and the cost of anodes per ton, P. The capital invested in copper in stock, including cathodes and copper leads, etc., is 1.3 A T P / D plus 4.05 R T / B, in which R is the price per ton of the refined copper of which the leads are made and B the current density per square inch in the copper conductors. In an example the price of the refined copper was $375 per ton; the price of anode copper, $350 per ton; the output of refined copper, 1,000 tons per year; the current density, 10 ampères per square foot at anodes; the price of copper sulphate crystals, $125 per ton; the thickness of the anode plate, 1 inch, and 250 ampères per square inch allowed in the copper current conductors; then his formulas give the total capital invested as $50,125. He then discusses the various items in the annual cost of refining. There is first the interest on capital invested; there is no depreciation except in so far as the market price may vary, but this cannot be readily taken into account; the annual cost of labor is 0.6 W T, in which W is the amount paid weekly in wages. The annual cost of melting refined copper is 1.25 M T, where M is the cost of melting one ton, and the factor 1.25 is to allow for remelting scrap anodes. The cost of fuel used for power per year is 0.0771 T D C, in which C is the cost of coal per ton. He then points out the great influence which the current density has upon the capital and annual outlay per ton of copper refined per year; there is, in fact, some particular current density which will yield the most satisfactory financial results, and this particular one varies with the price of coal, the cost of melting down each ton of refined copper into ingots, the rate of wages paid, the rate of interest paid upon the capital invested, and lastly, but most important, the difference in price at the works between the price paid for anode copper and the price obtainable for the refined copper, together with the value of the silver and gold separated from it, if this value goes to the refiner. The current density at the anode used in different plants varies between 1 and 15 amperes per square foot. He refers to a statement of Cowper-Coles that whereas formerly current densities of only 2 to 4 ampères per square foot were thought permissible, current densities of from 15 to 20 ampères are now said to be used in some establishments. The author states that he does not know of any electrolytic copper refinery in which a greater current density than about 15 ampères per square foot has been successfully used over any length of time, and he is strongly of the opinion that it cannot pay to use a greater current density than 16 ampères per square foot at the outside, if the product of the refinery is merely pure refined copper, and not, as in the Elmore process, some manufactured, or partly manufactured, article of copper, like sheets, tubes, wires, etc. He uses his formulas for calculating the different items of the capital investment and the annual charges, to show how all these items vary, when the current density is varied between 5 and 20 ampères per square foot, and from the results obtained it appears that the percentage profit on the capital invested, under the particular conditions stated, will be greater when the current density at the anode is about 15 ampères per square foot. The increase in the current density is not only limited by the question of prime cost, interest and depreciation, but also by other important factors, such as the alteration of the mechanical character of the electro-deposited copper on the cathode and the alteration of its chemical nature when the current density increases. Unless some special means are used, the copper which is deposited with current densities much above about 14 or 15 ampères per square foot, tends to take a crystalline and loose form, finally becoming long growths which may short-circuit a vat. Furthermore, if the electrolyte contains many impurities the high current density is favorable to the precipitation of arsenic and antimony together with the copper, thus greatly reducing its value. Concerning the series and parallel arrangement of the vats, he says that the amount of copper used in the connections between the vats and the dynamo is greater in direct proportion to the number of sets of vats there are in parallel; and the amount of copper in the form of copper is also greater per ton output of copper the greater the number of vats used on account of the extra connections between each vat. Economy in copper is, therefore, attained by having all the vats in series and having the vats as large as possible. The amount of copper is also less the greater the current density. He finally makes a few remarks on the size and the number of the vats and on the best voltage of the dynamos used for copper refining.

*Zinc Plating.*—To electrochemists, at least to those who have studied the relative electrochemical behavior of various metals, it is well known that when iron is in contact with zinc, or any other more electropositive metal, the iron cannot rust, as there exists continually an electrochemical-reducing action at the iron, at the expense of a corresponding oxidation of the zinc, and it is for this reason that galvanized iron does not rust. But this is also the reason why iron which has been covered with zinc by mere insertion in molten zinc is called "galvanized." The term galvanizing, as often applied to the process of coating the iron with zinc by dipping in molten zinc, is therefore quite irrational, as the only galvanic action which exists is the subsequent electrochemical-reducing action when the galvanized or electrofied iron becomes moist, and as the metal is then always cold the term "cold galvanizing," which is now often used for the process of electroplating with zinc, is therefore used for just the reverse process to which the term strictly applies, namely, for the reduction instead of the oxidation of the zinc. Similarly the term "electrogalvanizing" is quite incorrect, it being tautological. While such incorrect words may get into our not too consistent English language through the commercial elements, yet there seems to be no excuse why they should be sanctioned by electrochemists who understand their true meaning and origin. However this may be, a recent article by Burgess and Hambuechen in the *Electrical World and Engineer*, September 13th, under this unfortunate heading, is decidedly better than its title. In this they first discuss the prevention of the corrosion of iron by means of a coating of zinc and the advantages of the electrolytic

deposition of zinc over the hot process. The commercial processes by which "electrogalvanizing" is now being performed may be subdivided into two classes, according to whether use is made of soluble or insoluble anodes; the former is used almost exclusively in this country and the latter in England. The Cowper-Coles process employs a lead anode, which is practically unattacked by the sulphate solution, so that free acid is continually formed. The acidity of the solution, which is drawn from the tanks, is neutralized by bringing it into contact with zinc dust in contact with coke. The reason for prefering a soluble zinc anode is that circulation and regeneration of the electrolyte are theoretically unnecessary, and the use of auxiliary apparatus is done away with to a considerable extent; the amount of power required is also considerably smaller. The objections to zinc anodes are two: first, during the operation there forms upon the surface of the zinc a scale or coating, usually black in color, which interferes with the dissolution of the zinc; second, for satisfactory operation the solution must be kept at a certain degree of acidity. The deposition of a good quality of zinc coating depends almost entirely upon the composition of the solution; zinc sulphate is superior to chloride, but the addition of some other ingredient is required, among the most serviceable of which is aluminum sulphate, but the authors deny that in this case an alloy of aluminum and zinc is deposited. In the electro-deposition of metals for plating purposes they claim that the physical character of the deposit is better in being more compact, uniform and non-crystalline, when thrown out of solution by secondary rather than by primary action; in the solution under question, the aluminum is the more positive ion, which, on liberation, reacts with the zinc sulphate to deposit zinc. Alum is very frequently used in plating solutions, and its value lies in its being a cheap source of aluminum sulphate. When cast iron or iron containing a considerable amount of graphite is cleaned with acid, the graphite is unattacked, and as the iron is dissolved away, more and more comes to the surface, which then becomes an iron surface to which are attached innumerable small particles of graphite; in trying to electroplate this each particle not only refuses to receive a deposit, but protects the iron in its immediate vicinity from receiving it. This shows the necessity of using some other method than the acid alone for preparatory cleaning of cast iron; a cast-iron surface prepared by the sand blast receives its deposit most readily. The shape of the anode is an important factor in zinc plating; it should be designed so as to conform with the shape of the article to be plated, making the distance from the anode to each portion of the cathode as uniform as possible. As a general rule current density at the anode should be lower than at the cathode. To increase the depth of coatings, recourse is frequently had to "striking" solutions; one of its principles is the use in the zinc-plating solution of a metal salt, the metal of which is more electronegative than the zinc, the most satisfactory of such salts being tin chloride, which is added to the solution in small quantities from time to time. Another principle for striking solutions is the use of an electrolyte in which the zinc does not exist to any appreciable extent, as an electropositive ion, and in which it is, therefore, deposited entirely by a secondary reaction; Newman found the following solution very satisfactory: 0.4 pounds of potassium cyanide is dissolved in 1 gallon of distilled water, to which is added as much zinc carbonate as will dissolve; a current density of 14 to 25 ampères per square foot produces an excellent deposit; but the coating is formed slowly, and there is the disadvantage that the substance is very poisonous.

*Calcium Carbide.*—In an article by Pio in the Lond. *Elec.*, August 29th, he says that in Italy the calcium carbide industry is progressing rapidly, and the number of furnaces operated with continuous or polyphase current is continually increasing. It is only since last year that this industry has become profitable in Italy. Since 1896 acetylene has been introduced into commercial use in small villages, and is now being applied on railways for train lighting. Another field of application is the acetylene gas motor for small industries, but this class of motor has not yet been sufficiently improved to tempt experimenting on a commercial scale. The price of calcium carbide has been raised lately to $87.50 per ton, as against $50 last year, which seems to be the result of a syndicate which was recently constituted on the Continent. In a recent publication of Memmo the conditions required to render the industry remunerative are stated to be as follows: The price of the plant, including machinery, furnaces and all the necessary supplies, must be not higher than $100 per horse-power installed. A certain ratio between the number of tons of carbide produced and the number of effective horse-power must exist. The capital expended must be amortised in ten years; this corresponds to a sinking fund of $8 per ton, so that, including freight, loss, profits, etc., the price to customers does not exceed $60 per ton. At least 6 per cent. must be paid on the capital invested.

*Furnaces.*—Among the several articles that have appeared recently on electric furnaces is one by Haagn in the *Zeit. f. Elektrochemie,* July 31st; it is a Bunsen Society paper and describes a furnace for laboratory purposes, made by Heraeus. It has the advantage that it contains only 1-6 to 1-10 the weight of platinum, which is required in wire furnaces of equal size and durability; this allows, of course, a great saving; the platinum consist of foil 0.007 millimeter in thickness. The furnace is said to be very easily adjustable by the insertion and variation of a series resistance; it is said to follow exactly any variation of the currents. The tubes on which the platinum foil is mounted are best made of china or glass; magnesia is not suitable for high temperatures, as it then begins to become a good electrolytic conductor and the cathodic products of electrolysis destroy the platinum very quickly. At temperatures of 1,500° similar phenomena take place in the otherwise excellent and very refractory so-called Marquardt mass of the Berlin china factory; the temperature is limited by this phenomenon; he has, however, obtained a temperature of 1,700° for a short time, but the china then gets soft. The best form of the furnace is a tube, which is not too wide and not too short. The furnace can be made for any voltage up to 220; lower voltages are better for very high temperatures. In the discussion Heraeus said that he has succeeded in making a non-electrical furnace in which temperatures up to 2,200° can be produced; he uses for this purpose an iridium tube which is suitably placed in a lime furnace, and is heated by means of an oxy-hydrogen flame. The temperature was measured by means of a thermocell, consisting of wire of absolutely pure iridium and an alloy of 90 per cent. of iridium with 10 per cent. of ruthenium. This cell was compared up to 1,650° with a thermocell calibrated by the Reichsanstalt, and the higher values were "calculated."

On the subject of making steel there were two articles; in one by Seidener, published in the *Zeit. f. Elek.*, August 24th, the plant in Gysingen, Sweden, is described. When two years ago the first electric furnace was installed, it yielded 575 pounds in twenty-four hours with 78 kw.; it was used for experimental purposes, but now a larger furnace has been built, and it is claimed that with a 300 horse-power turbine, directly coupled with a generator, this new furnace will give 1,500 tons per year, which means that 72 horse-power give one ton per day. In other electric furnaces it is said that 50 or even 30 horse-power will give one ton of steel per day. It is suggested to use the wasted gases of blast furnaces to drive gas engines, and, if the power cannot be used otherwise, to utilize it in electric-steel furnaces.

The other is a note in the Lond. *Elec.*, September 5th, which states that the possibilities of the electric furnace as a rival of the blast furnace, for the smelting of iron ores, are now being tested at several places in Europe. The Stassano process has been under trial in a plant of 1,500 horse-power capacity at Darfo, in Northern Italy. After inspecting these

furnaces in operation about a year ago, Dr. Goldschmidt, of Essen, reported favorably on their prospects. But the capital available for these experimental trials has now been exhausted, and it was announced in January that the company owning the Darfo plant was in liquidation. From figures published by those financially interested in the Stassano process in 1899, it appears that 2.7 horse-power hours were expected to yield one kg. steel in the electric furnace, and that a saving of $7 per ton of steel was estimated as compared with the cost by the ordinary smelting process in Italy. Whether the liquidation of the company is due to the failure of the Stassano process to attain these results, or is simply due to a shortness of working capital, is not known. Similar trials of the electric furnace for the reduction of iron ores are being conducted at Prague in Austria, at Le Praz in France, and at Gysingen in Sweden, as noticed in the paragraph above, and at the latter place 1,200 kg. steel are said to be produced per day by the Kjellin process. If steel of good quality can be produced in a single operation by the electric furnace from iron ores of average composition, these new processes of ore reduction may have an important future.

*Chlorine and Soda.*—Although this is an important electrochemical industry, little has appeared in the press lately. Glaser gives an account, in the *Zeit. f. Elektrochemie*, August 7th, of an investigation of the Solvay-Kellner mercury cathode process on a laboratory scale, the chief results of which were that a low ampère hour efficiency is due chiefly to the depolarizing action of the chlorine on the alkali amalgam, and that the decomposition of the water is of less importance. Also that without a diaphragm a good efficiency can be obtained only at high-current densities, but with specially prepared diaphragms the efficiency is good at lower-current densities also. J. B. C. Kershaw begins an illustrated article on chlorates in the *Elec. Rev.*, October 4th. After some introductory notes on the reactions and their equations, he describes the Gall and Montlauer and the Carlson chlorate cells.

*Purification of Water by Ozone.*—There is an illustrated description in the *Sc. Am. Sup.*, August 23d, of the Siemens & Halske experimental plant for purifying water by ozone near Berlin.

## THEORETICAL AND EXPERIMENTAL.

*Faraday's Law.*—Fortunately for electrochemists this law, which is the foundation of the whole science of electrolysis, has successfully withstood all attacks made on it, even though at first sight it sometimes appears to fail. Nevertheless further proofs of its accuracy, such as those given in a recent A. A. A. S. paper by T. W. Richards, abstracted briefly in *Science*, August 22d, are always of interest, especially as he finds that the law applies to aqueous solutions and for ordinary temperatures. He reviews his researches in co-operation with Collins and Heimrod, and describes some more recent work done with the assistance of Stull. The weight of silver deposited in the "porous cup voltameter" of Richards and Heimrod, was compared with the weight deposited by the same number of coulombs from a solution of argentic nitrate in fused sodic and potassic nitrates at 300°. After making some corrections and subtracting the weights of alkaline nitrates included in the silver crystals, it was found that the weights were identical within the limits of error of the experiment, namely, about 0.005 per cent. This investigation places Faraday's law among the most exact and invariable of the laws of nature.

*Faraday's Law and Salt Vapors.*—That Faraday's law applies also to vapors is shown by Wilson in some experiments in which he passed electricity through flames containing salt vapors, an account of which may be found in the *Phil. Mag.* for August. Former experiments had shown conclusively that conduction through salt vapors is accomplished by means of ions of some kind and is therefore to this extent at least analogous to conductions through solutions. However, determinations of the velocities of the various ions in salt vapors show that the ions generally behave as if they were much heavier than single atoms, and that the positive ion always moves more slowly than the negative. The experiments described in the present paper show conclusively that above 1,300° C. there is a very close analogy between salt vapors and liquid electrolytes; Faraday's laws of electrolysis are strictly applicable to salt vapors. It is probable that the gaseous ions attract neutral molecules to themselves, which accounts for their small velocities; and apparently the positive ions condense many more molecules in this way than the negative, the latter, therefore, move much the faster. But this condensation, which appears to be peculiar to ions in the gaseous state, need not affect the number of ions produced by the dissociation of one salt molecule or the charges which they carry. He shows that a salt in the state of vapor gives rise to the same number of ions carrying the same charges as a salt in an aqueous solution; or, in other words, the capacity of a salt vapor for transporting electricity is the same as the capacity of an equal amount of salt in the state of solution. He describes in detail the arrangement of his experiments and gives curves showing how the current with a constant e. m. f. of 840 volts, varies with the temperature when solutions of one gram in a litre are sprayed. In each case the current at first rises rapidly to a nearly constant value, which is maintained over a wider or shorter range of temperature. On approaching 1,200° the current again begins to rise rapidly, and somewhere above 1,300° it suddenly attains a nearly constant value. This nearly constant value seems to represent the maximum current which the amount of salt passing through the tube can carry, for it is affected very little by increasing either the temperature or the e. m. f. This current he calls the "saturation" current for the particular salt used. The values of this maximum current are given for various salts in a table. From this table it appears that the maximum current of electricity transported by a salt vapor is proportional to the amount of salt passing between the electrodes, and that the saturation current with a definite amount of any salt passing between the electrodes is inversely as the chemical equivalent of the salt. This amounts to a proof that Faraday's laws of electrolysis apply also to the saturation current carried by a salt vapor. The amount of salt per second of unity electrochemical equivalent which would correspond to a current of 1 ampere, is 0.0101 milligram. Now, 1 ampère second liberates in electrolysis 0.0104 milligram of hydrogen, so that it appears that the factor of proportionality is nearly the same for salt vapors as for electrolytes.

*Unipolar Currents.*—A peculiar apparent departure from Ohm's law was observed by Christiansen in certain electrolytes, and is described in a paper in the *Ann. d Phys.* No. 8, an abstract of which may be found in the *Lond Elec.*, August 8th. He applies the term unipolar current to the current through mercurous nitrate in nitric acid, with mercury electrodes, because this current greatly depends upon the size of the cathode, but not on the size of the anode. The irregularity observed is, that under certain conditions the current is independent of the e. m. f. The nitric acid alone begins to be electrolyzed at 1.7 volts. The mercurous nitrate acid as a depolarizer, and is electrolyzed even at the smallest voltage, but after some time hydrogen is also evolved, giving a counter e. m. f. When the applied e. m. f. is increased, the counter e. m. f. also increases, and it appears that the difference of applied and counter e. m. f. remains constant up to 1.7 applied volts, and hence the current is independent of the e. m. f. It varies, however, directly as the surface of the cathode and as the percentage of mercurous nitrate.

*A Thermochemical Constant.*—That many curious and important relations exist between the constants of nature has long been suspected, and each discovery of a new one adds greatly to our knowledge of these important values of physical properties, which as a rule must be determined empirically, sometimes with great labor and doubtful accuracy. Any such

connecting links between two sets of apparently independent physical properties, at once give an indication of the accuracy and true values of both, and are a great help in discovering many of nature's secrets in relation to the complicated interconnection of various apparently independent properties. One such constant, for instance, is the product of the atomic weights of elements and their specific heats, and called the atomic heat, which is practically the same for nearly all the elements, and is really the number of calories required to raise 1 gram above 1° Centigrade. Another interesting constant relation of a similar nature has been found recently by F. W. Clarke, as shown in a recent A. A. A. S. paper, abstracted briefly in *Science*, August 22d. From a study of the heats of combination of organic compounds as determined by Thomsen, he finds a constant relation which is identical in value with the neutralization constant of strong acids and bases. Thomsen's data relate to substances burned as gas, with the production of gaseous carbon dioxide and liquid water. By a simple correction applied to the last-named factor all the equations of combustion may be reduced to the gaseous form throughout, under uniform conditions of temperature and pressure. When so adjusted, and by the application of a definite formula, nearly every equation yields the above-mentioned constant. Its average value in 65 cases is 13,773 small calories. From this constant and the original equations, the conclusion is reached that the absolute heat of formation, from gaseous, dissociated atoms of the aliphatic hydrocarbons and their simpler derivatives, is proportional to the number of atomic linkings within the molecule. In this calculation every linking counts as one, and single, double or triple unions between carbon atoms become identical as regards their thermal value. The conclusion is revolutionary, but it satisfies the equations which are otherwise indeterminate. The preliminary paper contains 66 verifications of the new law.

*Pulverization of Metals.*—Under certain circumstances a metallic cathode is disintegrated into an extremely fine powder which colors the solution almost like ink as it floats in it. Haber, who has made extended researches of this phenomenon, published an article in the *Zeit. f. Elektrochemie*, August 7th, in which he shows that it is due to the formation and subsequent disintegration of an alloy. He first makes some theoretical remarks on the potential of alloys in electrolytes, showing that an electrode, consisting of an alloy of two metals, has a certain distinct potential difference against an electrolyte, and this potential difference can be calculated theoretically, when the temperature and the ionic concentration of either the one or the other kind of ion is known; if the one ionic concentration is given, the other one is determined thereby. He makes some applications with reference to experiments of Herschkowitsch and others by himself and Sack. In the second part of his article he gives a general review of the phenomenon of the pulverization of metallic cathodes, a characteristic feature of which is that it takes place without any light or spark phenomenon. There are certain other kinds of pulverization of cathodes, but they do not take place during quiescent electrolysis and they have an intimate connection with electrostatic or electrothermic phenomena; the special case treated by him is a simple, purely electrochemical phenomenon. At a cathode in an alkaline solution, an alloy of the cathode material with the alkali metal is formed electrochemically; it could also be made chemically, and has the property of being decomposed in water with a simultaneous pulverization. This shows that cations, when giving off their charges at the cathode, do not rebound from the cathode, like rubber balls from a stone, but they enter into the cathode and form an alloy; this has long been known to be the case for mercury cathodes, but it is also the case for lead and tin, as is proved by the following: Alloys which pulverize, contain a relatively high percentage of the alkali metal, while those with a lower percentage decompose water quietly, without pulverization, but with a formation of a sponge on the cathodic surface. This formation of a sodium alloy at cathodes of lead and tin, is the intermediate process by which a vivid formation of hydrogen at these cathodes in sodium hydroxide is brought about. Some metals, especially platinum, do not pulverize, but become spongy on the surface; there is a great difference in this case between acids and alkalies; the hydrogen ions, with its high mobility, enter much more easily into the platinum than sodium ions. The essential formation of hydrogen in sodium hydroxide cannot be primary, as otherwise platinum would obtain a spongy surface just as well in alkali as in acid. When a cathodic point of platinum in sulphuric acid gets black, it is a case of the formation of a spongy surface. On the other hand, one should be careful not to consider deposits of impurities as a case of a formation of sponge. Billitzer replies to some critical remarks of Haber, in the *Zeit. f. Elektrochemie*, August 28th.

*Electrolytic Preparation of New Alloys.*—Coehn, in a Bunsen Society paper, shows that ammonium, like sodium, can be deposited on a mercury cathode and then forms an alloy, but the liquid state of mercury cannot be the reason for this deposition and of other metals of high solution tension, as it was impossible to get an ammonium deposit with a cathode of Wood metal; the reason why a deposit on a mercury cathode is possible, he believes, is that an alloy is formed. He then tried to deposit alloys of light and heavy metals from aqueous solutions, not by using a cathode of the heavy metal, but by depositing both metals at the same time from the solution. It has been repeatedly stated that the electrolytic deposition of nickel can be improved when a magnesium salt is added to the solution; the reason has not been clearly understood, but the author believes that it is because an alloy of nickel and magnesium is deposited. Such alloy deposits behave quite differently from deposits of pure nickel; while pure nickel does not adhere firmly, a nickel magnesium alloy does. He has made deposits of both upon sheet iron and polished copper sheets, and found that only the alloy deposits are adhesive, while pure nickel scales off. He tried in the same way to obtain an alloy of aluminum and magnesium, but was not successful. The paper is reprinted in the *Zeit. f. Elektrochemie*, August 14th.

*Cathodic Polarization in Dilute Sulphuric Acid.*—A method for measuring the value of the polarization at cathodes of different materials is described by Tafel in a Bunsen Society paper. It is analagous to Caspari's method of measuring the overvoltage required to develop hydrogen at cathodes of different materials; he determined the potential differences between cathode and electrolyte at which the first development of hydrogen bubbles takes place, and the excess over the potential difference between a hydrogen electrode and normal sulphuric acid was called by him the overvoltage of the respective metal; he found that of the metals investigated lead and mercury in pure sulphuric acid show the highest overvoltage; these are the same metals which Tafel has found to be the only suitable cathode materials for producing certain reductions. But while Caspari used a very small current density, Tafel uses comparatively high ones. He uses a rather large polished platinum anode, dilute sulphuric acid, and a smaller platinized platinum cathode; at a fixed current the e. m. f. has quite a distinct value which remains constant for several hours. He uses as anode a bright platinum pan, filled with sulphuric acid, in which is suspended, in a fixed position, a cylindrical platinized-platinum cathode, ending at the bottom in a half globe. This form of cathode can easily be reproduced in other materials, like lead. The e. m. f. is then measured again, while the same current flows, and the difference of the e. m. f. in the two cases of platinized-platinum and lead cathodes, is the "over polarization" of the lead cathode over the platinum cathode at the given current density, under the supposition that nothing is changed at the anode or in the electrolyte; the latter can be found out by again substituting the platinized platinum for the

lead electrode, when the e. m. f. should have the original value again. He says this method enables one to measure the polarization with an exactness of some thousandths of a volt. The paper is published in the *Zeit. f. Elektrochemie*, August 21st.

*Radio-Activity and the Chemical Atom.*—Although the subject of radio-activity may not properly belong under electrochemistry, there is a conclusion drawn in a recent long paper by Rutherford and Soddy in the *Phil. Mag.* for September, which may be of some interest here. They made a detailed investigation of the radio-activity of thorium compounds and found it to be accompanied by chemical changes in which new types of matter were being produced. They conclude that radio-activity is a manifestation of "subatomic chemical change," and the hope is expressed that radio-activity "affords the means of obtaining information of the processes occurring within the chemical atom, in the same way as the rotation of the plane of polarization and other physical properties have been used in chemistry for the investigation of the course of molecular change."

*Positive Electrons.*—A long series of experiments have been made by W. Wien, in which discharges in vacuum tubes were made with perforated cathodes; the positive electrons which travel towards the cathode pass through its perforations and can then be investigated in the same way as the negative electrons in cathode rays, etc. The results which he obtained concerning positive electrons, differ greatly from those formerly obtained for negative electrons, and he believes that certain differences in the color of the fluorescence produced make it possible that chemical influences take part in the phenomenon. For further information see the *Zeit. f. Elektrochemie*, August 14th.

*Electrolysis of Alkaline Chlorides with Platinized-Platinum Anodes.*—It has been known for some time that there is a distinct difference in the process of electrolysis, whether bright or platinized-platinum anodes are used, and, moreover, that the special method of platinizing the platinum also has some influence. Foerster and Mueller recently made extended researches of this action, which they published in a Bunsen Society paper which is reprinted in the *Zeit. f. Elektrochemie*, July 31st. They used the method of Lummer and Kurlbaum, and found that the average e. m. f. required for the electrolysis of alkaline chlorides is smaller for platinized-platinum anodes by 0.5 volt than for bright platinum. The formation of the chlorate proceeds about the same, although it starts somewhat later at the platinized anode than at the bright platinum, and the platinizing of the anode is of influence only upon the electrolytic processes preceding the formation of the chlorate. They made a very long investigation of the causes of this influence of the platinizing, and found that in the electrolysis of neutral solutions of alkali chlorides with platinized anode, the development of oxygen and the formation of chlorate depend only in a very small degree on the catalytic action of the platinum black, and must, therefore, be caused essentially by electrolytic action. In a great many experiments they found that the substitution of a platinized-platinum anode for a bright platinum plate of equal size, causes a considerable decrease in the voltage required for an electrolytic process, whether the electrolyte is sulphuric acid or sodium hydroxide or sodium chloride. This difference of voltage is not the same in all cases; at a current density of 0.067 ampères per square centimeter, it is, after 8 ampère hours for sulphuric acid 0.46 volt, after 3 ampère hours for sodium hydroxide 0.755 volt, after 10 ampère hours for chloride of sodium 0.82 volt; furthermore, at a current density of 0.017 ampère square centimeter after 11 ampère hours for sulphuric acid it is 0.308 volt, after 10 ampère hours for sodium hydroxide 0.665 volt, and after 11 ampère hours for sodium chloride 0.75 volt. This difference of voltage between the electrolysis with bright and with platinized-platinum anode depends, therefore, upon the nature of the electrolyte and more or less upon the current density, while with sodium hydroxide and sodium chloride it also changes considerably with the time. The phenomenon is very complicated and the causes do not seem to be clearly understood; the concentration changes at the anode can explain only a very small part of the voltage difference, but it seems that this difference occurs only at the moment when oxygen is developed at the anode. Caspari's overvoltage of oxygen is too small to explain the whole phenomenon, and besides, to call it overvoltage would only be giving a name to the phenomenon without explaining it.

*Hypochlorous Acid.*—On the basis of the measurements of Jakowin on the hydrolysis of chlorine in aqueous solutions, Luther, in the *Zeit. f. Elektrochemie*, August 21st, shows that it is possible to predetermine theoretically the electromotive behavior of hypochlorous acid, and makes some critical remarks on a recent experimental investigation of Mueller on the same subject.

*Velocity of Electrolytic Decomposition of Oxalic Acid.*—Akerberg has found that when a solution of sulphuric acid, containing oxalic acid, is electrolyzed between polished platinum electrodes, the oxalic acid is scarcely decomposed, but that when platinized-platinum electrodes are used it is readily decomposed. He believes that "the decomposition is, therefore, a secondary process, which is catalytically influenced by the platinum black; it is a purely chemical oxidation effected by the electrolytically separated oxygen. In concentrated solution, with low current densities, or at high temperature, the decomposition follows Faraday's law, but in more dilute solution the reaction is carried out by atomic oxygen." A note on his researches will be found in the Lond. *Elec. Eng.*, September 5th.

*Double Anode Process.*—The compound $(NH_4)_2PbCl_4$, may be prepared electrochemically by using simultaneously an anode of carbon and one of lead. This and the general principle of using two different anodes, one soluble and the other inert, which can be done to advantage for many purposes, are described by Elbs in the *Zeit. f. Elektrochemie*, July 31st.

*Cuprous Ions.*—The chemistry of cuprous compounds is discussed by Bodlaender in the *Zeit. f. Elektrochemie*, July 31st. Among other things he found that the cuprous ions are monatomic, not di-atomic.

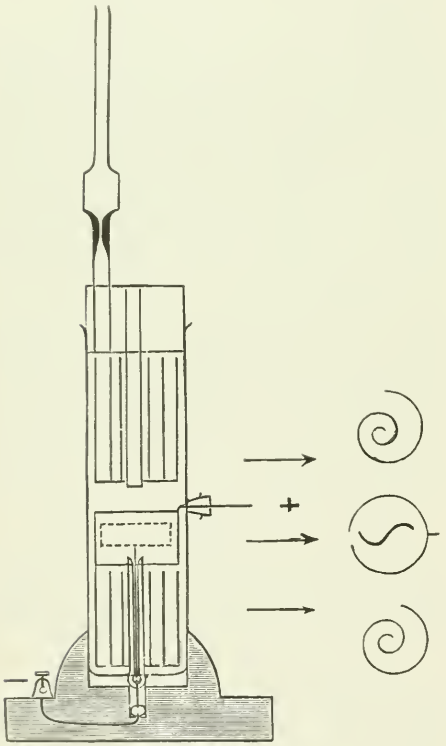
## PRIMARY AND SECONDARY BATTERIES.

*Accumulator Testing.*—The recent literature on batteries seems to be limited to the publication in the *Zeit. f. Elektrochemie*, August 21st, of the complete paper of Liebenow on the use of a third auxiliary electrode in accumulator testing, an abstract of which was noticed in this *Synopsis* last month.

## GENERAL AND MISCELLANEOUS.

*Silver Voltameter.*—The silver voltameter, with all its faults, must be considered a standard instrument until something better has been devised, and meanwhile any of the much needed improvements in it will be welcomed. In a modification described, with illustrations, by Farup in the *Zeit. f. Elektrochemie*, August 14th, apparently with the endorsement of Nernst, the process of weighing is simplified without sacrifice of accuracy; it is claimed to be even more accurate for very small currents. The solution consists of about 10 grams of silver nitrate, with about 15 of cyanide of sodium, dissolved to make 100 c. c. of solution, but with this electrolyte it is absolutely necessary to carefully exclude the oxygen of the air, for if it gains to the silver plate it will dissolve considerable of it. The principle of his apparatus consists in keeping the oxygen away from the platinum cathode by means of properly-arranged shields of silver. The adjoining diagram explains the arrangement. A glass tube, forming the vessel, is provided at the bottom with a platinum wire, which is melted through it and leads to a capillary tube, by which the corrugated platinum cathode is supported. The anode is a sheet of silver which surrounds the platinum electrode, the

current being lead into it from the side. Above and below the two electrodes sheets of silver in spiral form are provided for removing the oxygen which is originally in the solution, or diffuses into it during the test. In order to diminish this diffusion as much as possible, the glass is so completely filled with solution that when the rubber stopper is put in, the solution enters the pipette tube which is set into the rubber stopper. The lower end of the platinum wire dips into a drop of mercury to make a good contact. In order to remove all the oxygen originally in the electrolyte, it is necessary to fill the voltameter some time before the circuit is closed. At the end of the test, the platinum electrode is weighed without any other care, except to clean it in distilled water and dry it for a few seconds over a flame.




SILVER VOLTAMETER.

*Goldschmidt Process.*—Although this process is not electrochemical, it is of interest here in that aluminum is the fuel. Houllevique, in the *Jour. de Phys.*, May, abstracted in the Lond. *Elec.*, August 8th, describes how he prepared pure iron in this way. He recommends the use of at least 3 kgr. of the mixture of aluminum filings, washed in petroleum essence and dried, and pure sesquioxide of iron, free from sulphur and carefully dried, in excess of about 15 per cent. over the amount required for the chemical reaction, and crucibles lined with magnesia. The addition of 20 per cent. of powdered cryolite to the mass increases the fusibility and raises the yield from 30 to 53 per cent. The slightest trace of sulphur is very obnoxious. There is even greater difficulty in obtaining pure aluminum free from fatty matter.

*Magnetic Separation of Zinc Blende.*—The magnetic separation of zinc blende from mixed sulphide ores by means of Wetherill magnetic machines, is now being carried on as a regular process at Denver, Colo., according to the *Eng. and Min. Jour.* for August 16th. The ground product is distributed among eight Wifley tables, which separate it into galena-pyrites and pyrites-blende classes, and the latter are then passed over the two Wetherill machines, each having three magnets. These produce a blende product, assaying about 50 per cent. Zn, 10 to 12 Fe and 1 Pb, which is sold to zinc smelters, while the rest is sold to the lead smelters. One per cent. of iron in the blende makes it susceptible to the intense effect of the Wetherill magnets, while pyrite and galena are not affected. The capacity of the zinc mill at Denver is about 40 to 45 tons of crude ore per day.

*Effect of Atmosphere on Aluminum Alloys.*—Wilson, in a British Association paper, describes tests of the electrical conductivity of certain aluminum alloys as affected by exposure to the London atmosphere. The specimens are in the form of wire, 0.126 in (3.2 mm) diameter, supported on a wooden frame; they were exposed on the roof of a building for thirteen months. The position of aluminum in the electrochemical series with respect to the other substances in the analysis is as follows: Al, Mn, Zn, Fe, Ni, Cu, Si. Copper produces corrosion, which increases with its percentage. Nickel alone has considerable effect, but if alloyed with copper the conductivity slightly increased during exposures. The results of the analysis of the different experiments before and after exposure are given in a table. For exposed-light-aluminum alloys it appears that copper should not be used alone; the presence of equal amounts (about 1 per cent.) of nickel and copper certainly reduces conductivity to a small extent, but the gain in mechanical properties and in resistance to corrosion are great. For further details see Lond. *Elec.*, September 19th.

*Electro Analysis.*—In the *Zeit. f. Elektrochemie,* June 19th, Hanaman gives an illustrated description of an apparatus for this purpose, in which all the different devices and accessories are combined.

The methods of Bindschedler for the electrolytic estimation of mercury, that of Brunck for the estimation of bismuth, and that of Moltke-Hansen for the separation of lead and manganese, are described by Arth in *L'Eclairage Elec.*, August 2d.

*Course in Physical Chemistry.*—The course at the University of Bonn is described with illustrations by Loeb and Rimbach in the *Zeit. f. Elektrochemie,* July 10th.

## CURRENT NOTES.

**American Electrochemical Society.**—The next meeting of the American Electrochemical Society will probably be held in New York City in the spring of 1903; this will be the annual business meeting, with election of officers, etc. We understand that it has been suggested to hold, in the summer of 1903, a joint meeting with the American Institute of Electrical Engineers, at a place near Sault Ste. Marie, Ont. The idea has much to be recommended, but no official steps have yet been taken. From another side it has been suggested that a joint meeting of the American Chemical Society and of the American Electrochemical Society should be arranged. There is no doubt that such meetings would further the interests of electrochemistry, and the social intercourse between electrochemists and their colleagues from the purely electrical and the purely chemical profession would be of value to all concerned. We hope, therefore, that these suggestions which have so far been made only by individual members will be received with favor by the councils of the three societies, and that they may be carried into effect.

**American Aluminum Association.**—The second annual meeting of the American Aluminum Association was held at Pittsburg, Pa., September 18th, 19th and 20th. More than 90 per cent. of the entire aluminum interests of America were represented by delegates. Matters of business relating to the improvement of trade conditions were discussed. A paper on the future of aluminum industry was presented by Dr. Joseph W. Richards. Officers for the ensuing year were elected, Mr. Joseph A. Steinmetz, of Philadelphia, president; Mr. Wagner, of Sydney, Ohio, vice-president; Mr. Palmer F. Langdon, of New York, secretary and treasurer. Various committees were appointed to formulate trade relations and to insure the proper and correct application of the metal to approved uses. It was determined to be represented at the Louisiana Purchase Exposition at St. Louis in 1904 by a large and comprehensive associated display, showing the history of the metal from its discovery, its ores, treatment, processes of reduction, and applications of the metal, as well as a complete display of all articles thus far successfully made of aluminum. The Metallurgical Committee, who will have this development in hand, is composed of Dr. Joseph W. Richards, who has been ever identified with aluminum and its history and metallurgy; Mr. Arthur V. Davis, general manager of the Pittsburg Reduction Co., the largest producing company of aluminum in the world, and Mr. Joseph A. Steinmetz, who has been for some ten years closely associated with the metal and its fabrication and general application in the arts and sciences.

**Mineral Products of the United States.**—The United States Geological Survey has published a very interesting statistical table showing the mineral outputs of the United States in the ten years, 1892 to 1901. Among the metallic products we find aluminum, the output of which in 1892 was 259,885 pounds, with a value of $172,824, and in 1901, 7,150,000 pounds, with a value of $2,238,000; that is, the output of aluminum in 1901 was more than 27 times greater than in 1892, while the value per pound in 1901 was less than one-half of that of 1892. At the end of this table interesting statistics of the total value of the mineral products since 1880 are given: $369,319,000 in 1880; $619,648,925 in 1890, and $1,092,224,380 in 1901. The table has been compiled by Director Charles D. Walcott, under the supervision of Dr. David T. Day.

## CORRESPONDENCE.

### THE ELECTROMOTIVE FORCE OF THE DANIELL CELL

*To the Editor of the Electrochemical Industry:*

Sir:—Professor Carhart is quoted in your September issue, page 9, in his "Contributions to the Theory of Concentration Cells," as saying that the increase of the electromotive force of the Daniell cell with the increase of density of the copper sulphate solution, and its decrease with increase of density of the zinc sulphate solution, is clearly explained by his thermo-electric theory, and that "the only other explanation of this fact ever given is based on osmotic pressure."

Without going into any criticism of the thermo-electric theory of concentration cells (which theory the writer is not yet ready to accept as explaining the *origin* of their electromotive force), the writer wishes to call attention to the fact that another explanation of the Daniell cell phenomenon is to be found, which is based neither on a thermo-electric theory, nor on the theory of osmotic pressure, but on a few well-demonstrated *experimental facts.*

We all agree that the difference in the heats of formation of zinc sulphate and copper sulphate, in aqueous solution, is the chief, if not the only, source of the electromotive force of the cell in question. But, these heats of formation vary with the concentrations of the solutions formed, both of them increase as the solutions formed are the more dilute. Therefore, if the copper is deposited from a more concentrated solution, in which the formation heat of the copper salt is less, the value of the heat energy transformed in the cell is increased, and its electromotive force correspondingly *increased.* If, on the other hand, the zinc is dissolved into a more concentrated solution, the formation heat of the zinc salt is less, and the electromotive force of the combination is correspondingly *decreased.*

Similar thermochemical considerations, of the varying solution heats of sulphuric acid of varying dilutions, are applicable to explain part of the variations of electromotive force of the lead accumulator.

These thermochemical data are such well-established facts, and their applicability to explain the variations in the Daniell cell referred to, as well as to concentration cells in general, so patent and necessary, that it seems that the statement of Prof. Carhart must be revised so as to take these into account.

Joseph W. Richards.

Lehigh University.

## BOOK REVIEWS.

Monographien über Angewandte Elektrochemie. I. Band: Die Elektrolyse des Wassers. Von Viktor Engelhardt. Halle: Wilhelm Knapp, 1902. 117 pages, with 90 illustrations and 15 tables. Price, 5 marks.

This is the first volume of a series of monographs, to be published at regular intervals on special subjects of applied electrochemistry. Each volume is to give a full and detailed report of the development and present state of the subject treated in it. Viktor Engelhardt, the chief chemist of the Siemens & Halske Co. in Vienna, will be the editor of the whole series. He is also the author of the first volume which deals with the electrolysis of water, its methods and its use.

The author first gives some historical notes on early investigations, and notices the physical and chemical constants which enter into the problem. He then describes in detail and at length the different methods which have been devised for the electrolysis of water. The methods for producing oxygen and hydrogen separately are divided into three classes. In the first one porous diaphragms of non-conducting material are used; in this class are the processes of d'Arsonval, Latchinoff, Ducretet, Renard, Delmard, Bell, Schmidt. In the second class solid, non-porous and non-conducting diaphragms are used which, of course, do not separate the whole electrolyte into entirely separate parts, as globes or bells of non-conducting material are placed around the electrodes. Here we have some well-known laboratory apparatus, and also the methods of Ascherl, Schoop, Hazard-Flamard, Verney. The third class is similar to the second, but conducting non-porous diaphragms are used and the e. m. f. is kept low enough to prevent a diaphragm from acting as cathode on one side and as anode on the other side. In this class are described the methods of Garuti, Siemens Bros. and Obach, Schuckert & Co. All these methods are described in detail with many illustrations. The author then describes the various voltameters in which oxygen and hydrogen are produced together, and notices the attempts which have been made to obtain pure oxygen by electrolysis without the use of diaphragms; this may, for instance, be done by using a depolarizing cathode which is reduced during electrolysis. This chapter is concluded by a table which gives a good review of the different patented processes and their particular features.

In the second half of the book the author discusses the commercial aspect of the problem and the commercial use of the products of the electrolysis of water. He gives data on the cost of the gases when produced by the different processes and then discusses the following commercial applications: oxygen and hydrogen together for producing high temperatures, for lighting, for blasting; hydrogen for filling balloons, for soldering and for lighting. The book is concluded by an appendix containing several tables, and by an index giving the names of authors and inventors.

The Copper Handbook. Vol. II. Compiled and published by Horace J. Stevens, Houghton, Mich. Paper, $1; buckram, $2; full morocco, $3.

This handbook is designed chiefly for business men and others who are financially interested in copper mines.

For such, as well as for the general scientific public, the book is valuable, for in it are compiled many facts about the history, metallurgy, mining and uses of copper.

Almost every mine in the world receives a short notice, and the great mines of Montana, Arizona and Michigan are the subject of short historical sketches. As the information on which these sketches are based is semi-official, it can be scarcely doubted that it is fairly reliable. But the outputs of some of the smaller mines is rather an estimate of what might be done under most favorable conditions than a statement of past production.

The chapter on general copper statistics is especially valuable, and contains many useful tables, as, for instance, a table converting London price of copper expressed in pounds sterling per long ton, to cents per pound—the American units. In this connection, it is well to note that there are four tons used in weighing copper and its ores. Troy, avoirdupois, metric and long tons. This certainly throws a burden on the statistician of copper.

For the class for which this book is written the book certainly is a useful compendium and a handy book to have near at hand.

## BOOKS RECEIVED.

Monographien ueber angewandte Elektrochemie. Vol. II. Die Gewinnung des Aluminiums. By Adolphe Minet Translated into German by Dr. Emil Abel. Halle: Wilhelm Knapp. 129 pages, with 57 illustrations and 15 tables. Price, marks 7.

Monographien ueber angewandte Electrochemie. Vol. III. Die Darstellung des Chroms und seiner Verbindungen mit Hilfe des elektrischen Stromes. By Dr. Max LeBlanc. Halle: Wilhelm Knapp. 110 pages. Price, marks 6.

Einfuehrung in die Elektrochemie. Nach der elektrolytischen Dissociatiationstheorie. By Peter Gerdes. Halle: Wilhelm Knapp. 124 pages, with 48 illustrations.

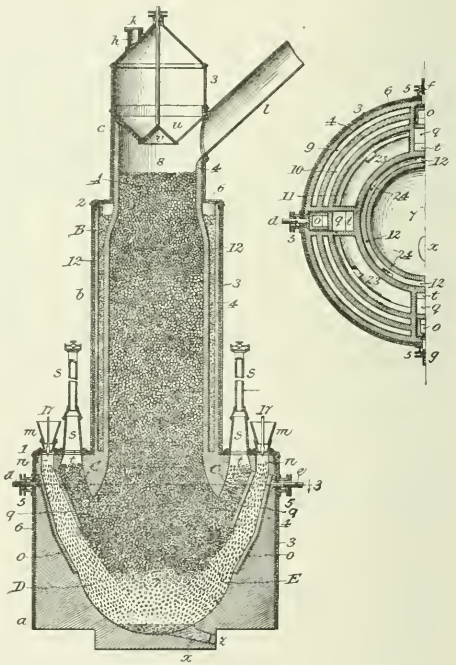
The Mineral Industry. Its Statistics, Technology and Trade in the United States and other countries to the end of 1901. Founded by Richard P. Rothwell. Edited by Joseph Struthers, Ph. D. Vol. X. New York: The Engineering and Mining Journal. 920 pages. Price $5.

The Optical Rotating Power of Organic Substances and Its Practical Applications. By Dr. Hans Landolt, assisted by Dr. O. Schoenrock, Dr. P. Lindner, Dr. F. Schuett, Dr. L. Berndt and Dr. T. Posner. Second edition. Authorized English translation with additions by Dr. John H. Long. 751 pages with many illustrations. Easton, Pa.: The Chemical Publishing Co. Price, bound in cloth, $7.50.

## A CLOSED CONTINUOUS-WORKING ELECTRIC FURNACE.

The adjoining illustrations represent a type of electric furnace invented by E. R. Taylor, Penn Yan, N. Y., and primarily intended and used at present for the manufacture of carbon bisulphide. The principle of this latest type permits, however, a much wider application and the inventor states that he will soon apply it to the manufacture of other chemicals.

One of the distinguishing features in the latest type is the electrodes, which are self-renewing and feed themselves by gravity. As shown in the cut the furnace is vertical shaped, and on the inside at the bottom is rounded. The inlet pipees are designated by *mm*, *ss* and *h*. There are the sources of current at *d* and *e*, and connected to them on the inside are trough-shaped conduits which extend towards the bottom of the furnace. The lower part of the conduits are constructed at an angle so that the descent of the fragmentary matter is retarded and thrown inwardly towards the middle of the working chamber, where the heat zone is. The electrodes, feeding themselves by gravity, descend into the bottom of the working chamber from the outlet of the conduits *o*, and gradually come close together at the bottom. They are naturally thinnest where they come together, thus affording the necessary resistance, and converting the electricity into heat. The heat zone is thus located at the bottom. There are four



TAYLOR ELECTRIC FURNACE.

electrodes, which are diametrically opposite each other, and are situated 90° from each other.

The fragmentary carbon is introduced at *ss* or at *h*, and the crushed sulphur at *mm* and corresponding points around the furnace. The sulphur is thrown towards the bottom of the working chamber and thus it is fused at the same time with the carbon. The vapors ascend up through the furnace through the pipe 1 into condensers, and are there liquefied. At the bottom of the furnace is a tap-hole *x*, where the residue may be taken out.

The furnace is continual in its operation, and at no time does the current have to be shut off to insert fresh material.

The manufacture of carbon bisulphide is carried on extensively at this plant, and there is a good market for it. Carbon bisulphide is used in large quantities for exterminating the insects and small animals which destroy thousands of dollars' worth of grain annually; for this purpose no exterminator is said to have given as much satisfaction as carbon bisulphide. It is also used for other purposes, among which may be mentioned the following: As a disinfectant; for preserving perish-

able articles; with chloride of sulphur for vulcanizing india rubber; for extracting oil from seeds, wool, bones, etc. Carbon bisulphide evaporates quickly, and the fumes, which are heavy, descend into the grain, cracks and holes, and effectually destroy all animal life. Attention has recently been called to important new applications in London *Engineering*, where, it is said, that the economy of cyanide recovery processes in coal-gas manufacture is threatened by a new process depending on the use for the same purpose of carbon bisulphide.

## A NEW STORAGE BATTERY.

An interesting cerium storage battery has recently been devised by Dr. Auer von Welsbach, the famous Austrian chemist and inventor of the incandescent gas-light mantle and of the osmium electric incandescent lamp. It may be called a cerium battery because it is the use of cerium salts which is its peculiar novel feature. To characterize the cell in a general way, it may be said to be of the type of the Bunsen battery. It is a double fluid cell with diaphragm. The positive plate (the plate where the current leaves the cell during discharge) is inert; the negative plate is amalgamated zinc; the electrolyte at the negative plate is

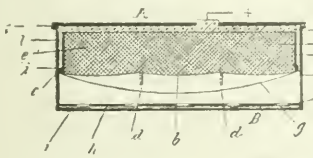


FIG. 1.—WELSBACH STORAGE BATTERY.

zinc sulphate. So far is the construction the same as that of the Bunsen cell. But while in the latter strong nitric acid is used as the depolarizer at the positive plate, Auer von Welsbach uses a specially prepared saturated solution of a double salt of sulphates of cerium and zinc; as positive plate he uses a finely divided fabric of elastic graphitized carbon. During discharge zinc dissolves and ceric sulphate is reduced to cerous sulphate. During charge zinc is deposited upon the electrode, and at the other end cerous sulphate is oxidized to ceric sulphate.

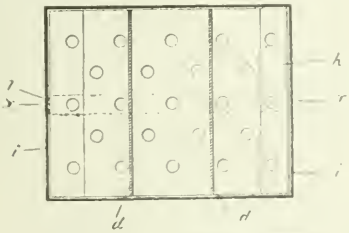


FIG. 2.—WELSBACH STORAGE BATTERY.

The construction of the battery is shown in the adjoining diagrams. Fig. 1 shows a vertical section, Fig. 2 a horizontal section. The negative plate is a perforated sheet of amalgamated zinc *h*, 1 mm. thick, covered with mercury; it is in contact with the amalgamated iron strip *l*. The positive electrode consists of a fabric or of foils of elastic graphitized carbon *e*, which is contained in a celluloid frame *c*, which is open at the upper and at the lower side. At the upper side a graphite plate *f* is pressed slightly against the fine graphite fabric—*d* and *d* are small cross pieces which hold the graphite fabric in position. At the lower rim of the celluloid frame the arched diaphragm *g* is attached; it has to prevent any pieces of carbon from falling down upon the zinc plate; it also prevents mixing of the electrolytes, and causes any bubbles of hydrogen gas which arise, to escape upwards along the sides.

To set up the battery, the celluloid frame containing the graphite fabric is placed into the box containing the negative plate; the upper part with the graphite fabric is then filled with the cerium electrolyte. If the battery is used for stationary purposes, stirring is necessary. For service on automobiles it is claimed that the vibrations of the carriage are sufficient. The cell is said to be best adapted to purposes when the discharge follows the charge immediately.

The e. m. f. of the battery is claimed to be higher than that of the lead accumulator, the capacity, per unit of weight, is said to be several times that of the lead accumulator.

## PERSONAL.

The following is the complete alphabetical list of the members and guests who registered at the Niagara Falls meeting of the American Electrochemical Society:

E. G. Acheson, Chas. E. Acker, Niagara Falls, N. Y.; W. D. Bancroft, Ithaca, N. Y.; H. T. Barnes, Montreal, Que.; Chas. B. Barton, Berlin, N. H.; Mrs. J. Warner Batt, Albany, N. Y.; Geo. H. Baynes, Jr., Ithaca, N. Y.; F. M. Becket, Niagara Falls, N. Y.; C. H. Benjamin, Buffalo, N. Y.; H. S. Blackmore, Mt. Vernon, N. Y.; Earl Bogue, Ithaca, N. Y.; Chas. S. Bradley, Geo. F. Brindley, Niagara Falls, N. Y.; Oliver W. Brown, Bloomington, Ind.; Wm. Hand Browne, Jr., New York City; C. F. Burgess, Madison, Wis.; Miss Burnell, Charlotte, N. C.; Eugene A. Byrnes, Washington, D. C.; Henry S. Carhart, Ann Arbor, Mich.; H. R. Carveth, Ithaca, N. Y.; H. B. Cho, New York City; Chas. W. Coit, C. A. Collins, Jr., Niagara Falls, N. Y. Miss L. Conord, Miss A. Conord, West Hoboken, N. J.; Alfred H. Cowles, Cleveland, Ohio; G. E. Cox, Niagara Falls, N. Y.; F. B. Crocker, New York City; E. A. Deeds, Niagara Falls, N. Y.; L. C. Dodd, Buffalo, N. Y.; Norman Dodge, Philadelphia, Pa.; W. F. Doerflinger, Niagara Falls, N. Y.; C. S. Doggett, E. Chicago, Ind.; Sarah R. A. Dolley, Rochester, N. Y.; Wm. H. Dopp, Buffalo, N. Y.; Chas. A. Doremus, Gustav Drobegg, New York City, Henry H. Durham, G. W. England, R. W. England, Buffalo, N. Y.; Francis A. J. Fitzgerald, Niagara Falls, N. Y.; L. H. Flanders, Pittsburg, Pa., Geo. W. Fletcher, Brooklyn, N. Y.; Francis Forbes, New York City, S. P. Franchot, Niagara Falls, N. Y.; Oliver P. Fritts, Denver, Colo., Austin Fritchle, Mrs. Austin Fritchle, Tuskaloosa, Ala.; Wm. C. Geer, Ithaca, N. Y.; A. E. Gibbs, W. T. Gibbs, Niagara Falls, N. Y., W. E. Goldsborough, St. Louis, Mo., Chas. J. Greenstreet, Coal City, Pa., F. Haber, Karlsruhe, Germany, Max M. Haff, C. M. Hall, S. F. Hall, Niagara Falls, N. Y.; C. Hanbuechen, Madison, Wis.; Wm. D. Harris, Philadelphia, Pa., Edward Hart, Easton, Pa., Walter H. Hart, Philadelphia, Pa.; J. C. Hecklau, Buffalo, N. Y., Carl Hering, Philadelphia, Pa.; Aldus C. Higgins, Worcester, Mass.; Wm. H. Hoskins, Chicago, Ill., G. M. Howard, Philadelphia, Pa.; Henry Howard, Brookline, Mass., R. S. Hutton, Manchester, Eng., Alois von Isakovics, New York City, Geo. N. Jepson, Worcester, Mass., Woolsey McA. Johnson, New Brighton, N. Y.; Louis K. Kimberg, Madison, Wis.; N. S. Keith, New York City, R. N. Kefid, Buffalo, N. Y., A. S. Krebs, Washington, D. C.; A. A. Knudson, New York City, H. S. Lamdale, Buffalo, N. Y.; A. B. Lambert, Great Works, Me.; Miss C. A. Lee, Rochester, N. Y.; P. M. Lyon, Pittsburg, Pa.; C. F. Lyon, Iowa City, Iowa, D. R. Lyon, Niagara Falls, N. Y., F. J. Mackie, Chicago, Ill.; Albert Marsh, Niagara Falls, N. Y., A. B. Martin, Jr., Washington, D. C.; Wm. O. Mathews, Miss W. O. Mathews, Cleveland, Ohio; F. G. Maxwell, Brooklyn, N. Y.; James J. McComas, Coldwater, Pa.; J. A. McKittrick, Schenectady, N. Y., James McMahon, Niagara Falls, N. Y.; Jas. A. Miller, Buffalo, N. Y., W. J. Moore, Toronto, Ont.; Max Moore, Niagara Falls, N. Y.; Russell F. Morgan, Buffalo, N. Y.; Henry G. Morris, Philadelphia, Pa.; H. B. Morse, Buffalo, N. Y., E. H. Morse, New York City, R. J. Nolan, Schenectady, N. Y., E. M. Olcott, Philadelphia, Pa., J. G. O'Neil, Niagara Falls, N. Y.; J. A. Parsons, Baltimore, Md., Geo. W. Patterson, Ann Arbor, Mich., C. L. Peirce, Niagara, N. Y., Frank C. Perkins, Buffalo, N. Y., Joseph Perkins, Cleveland, Ohio, Herbert W. Pike, Philadelphia, Pa., Henry Nott Potter, New York City, E. F. Price, Niagara Falls, N. Y., S. Reed, Washington, D. C.; C. L. Reed, Indianapolis, Ind., Arno Reichenstahl, Miss Arvil Reuter, Pittsburg, R. I. Jones, W. Richards, Wm. Richards, Bethlehem, Pa.; W. A. Robbins, Miss W. A. Robbins, Camden, N. J., J. C. Roberts, A. G. Rogers, Niagara Falls, N. Y., Hugh Rogers, E. F. Roeber, C. W. Rogers, Indianapolis, Ind., E. R. Roseberg, Troy, N. Y., S. H. Ross, E. G. Spink, Philadelphia, Pa., Bertram E. Sanborn, Boston, Mass., F. E. Schermerhorn, New York City, Geo. O. Seaton, Hampton Roads, Va., Samuel Sheldon, Brooklyn, N. Y., E. S. Shumway, Ithaca, N. Y., John L. Smith, Niagara Falls, N. Y., A. W. Smith, Cleveland, Ohio, Edward W. Smith, Philadelphia, Pa.; W. O. Snelling, Washington, D. C., C. C. Sneden, New York City, Elmer A. Sperry, Mrs. C. A. Sperry, Cleveland, Ohio; Thos. E.

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We reproduce herewith a photograph of the foreign guests of the American Electrochemical Society at the Niagara Falls meeting. Prof. F. Haber, of the Institute of Technology, of Karlsruhe, Germany, and Mr. R. S. Hutton, of Owens College,

F. HABER AND R. S. HUTTON.

Manchester, England. We are indebted for this picture to Mr. Walter R. Taggert, of the University of Pennsylvania, who took the snap-shot on the veranda of the International Hotel at Niagara Falls. Mr. Hutton has meanwhile returned to England. Professor Haber is in the West, and will sail for Germany in November.

Mr. Titus Ulke has returned to Sault Ste. Marie from an extended trip to the West.

## OBITUARY.

Sir Frederick Abel died suddenly on September 6th, at his residence in Whitehall Court, London. He has been best known as the chemist to the British War Office, from 1854 to 1888. In this capacity he conducted the researches which led to the adoption of the smokeless powder or cordite. He took great interest in technical education and research, and was also intimately connected with the electrical profession, being in 1877 the president of the British Institution of Electrical Engineers. He also served at various times as president of the Chemical Society, the Institute of Chemistry, the Society of Chemical Industry, and the Iron and Steel Institute, and was a fellow of the Royal Society. Among his numerous writings was a treatise, in 1884, on electricity applied to explosive purposes. He was born in 1827 and entered in 1845 the Royal College of Chemistry, where he obtained his chemical training under the famous German chemist, A. W. von Hofmann.

## INDUSTRIAL NOTES.

Mr. Marcus Ruthenberg, Philadelphia, is said to contemplate installing a very large reduction plant for the Pennsylvania Steel Co.

Mr. J. L. Malm, Marysville, Mont., is installing an electrical precipitation plant in connection with cyaniding operations, the only one in the State of Montana.

A firm in California is said to be introducing an electrolytic-alkali process, the first at the Pacific Coast.

We have received from President A. E. Newton, of the Cutter Electrical and Mfg. Co., Philadelphia, their recently-issued most-handsome book, "ITE Switchboard Practice." It is one of the best examples of the modern type of trade catalogues, print and illustrations being beautiful. The principle of the automatic circuit breaker and its application to all the various purposes for which it may be used are discussed, the descriptions being profusely illustrated. Of special interest to our readers will be the chapter on the use of the circuit breaker in connection with storage batteries. The book also contains chapters on measuring instruments (Keystone instruments) and on switchboard construction.

Water-Power.—The firm of Pepper & Register, Philadelphia engineers and general contractors, are developing a large water-power on the St. Lawrence River, about 18 miles from Ogdensburg, N. Y. The complete hydraulic development is to be installed at once, and the electrical power to be installed in increments when sold to consumers. The total development is for 34,500 mechanical horse-power. The power plant is admirably located. No inland port could have greater advantages for shipping. The region of the Great Lakes, with its resources and enormous trade, and the entire basin of the St. Lawrence are tributary to it, and bring the development in close touch with the chief centers of the American continent. The plans proposed by Pepper & Register are for extensive piers and wharves on the St. Lawrence River. The plans also contemplate excellent railroad connections. By the construction of a short road to Ogdensburg, direct connection is made with the New York Central and Hudson River Railroad, the Grand Trunk Railroad, the Rome, Ogdensburg and Watertown and the Rutland Railroads. The place is admirably suited for electrochemical industries to settle down. The natural advantages for construction of a larger power plant at Waddington are such that the cost of development will be low. Pepper & Register are prepared to make contracts for the sale of power, to be delivered within twelve months, which will be as soon as it would be possible for industrial enterprises to complete their buildings and establishments ready to receive this power.

## DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

*Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.*

*This digest of electrochemical United States patents prior to July, 1902, will be one by classes, setting out for comparison in each class those devices which have the same object, or those methods which seek the same results. In each class the patents will be arranged chronologically. The digest will be complete in the sense of covering every point which is touched upon in the original specification.*

ELECTROLYSIS OF SODIUM CHLORIDE WITH MERCURY CATHODES.—(CONCLUDED.)

578,457. March 9, 1897; C. Kellner, Vienna, Austria-Hungary. Mercury cathode flows in helical path under the anode.

Withdrawn into decomposition vessel, where amalgam flows over inclined riffle in ammonium nitrate solution, forming ammonia and caustic soda.

Cathode in this vessel and current generated is used as desired.

Mercury cooled and return.

586,635. July 20, 1897; H. C. F. Stormer, Christiania, Norway.

Amalgam-washing apparatus.

Amalgam lifted in perforated tray and flows down through water over rods of glass, ebonite or carbon.

586,729. July 20, 1897; C. Kellner, Vienna, Austria-Hungary.

Mercury cathode descends in helical or zigzag channel, passing repeatedly through openings in a non-conducting partition, and coming alternately into contact with the electrolyte and the oxidizing solution.

In latter solution is short circuited with metal-containing vessel.

Vertical tubular carbon anode serves as feed tube for sodium chloride in one modification.

588,276. August 17, 1897; C. Kellner, Vienna, Austria-Hungary.

Mercury containing sodium withdrawn from decomposing cells through rocking box to break connections, and passed through a series of oxidizing cells, between which electrical connections are likewise broken.

Each oxidizing cell contains a cathode to which amalgam acts as anode. These cells are electrically connected in series, whereby is obtained a current of potential sufficiently high to be employed in decomposing cells.

600,211. March 8, 1898; H. C. F. Stormer, Christiania, Norway.

Reduces decomposition of water of electrolyte by separated sodium, by gently agitating the mercury cathode, whereby portions of the superposed amalgam film are continuously dissolved by, or diffused throughout, the body of the mercury.

Uses vertically reciprocating perforated plates or horizontally reciprocating riffled plate.

608,300. August 2, 1898; B. E. F. Rhodin, Sault Ste. Marie, Can.

Modification of Rosenbaum's device (546,348).

Mercury cathode in circular cell having radial ribs.

Anodes in circular bell having plurality of open-ended tubes projecting into mercury.

As anode cell revolves, amalgam formed in tubes comes in contact with water in external cell.

614,353. November 15, 1898; H. C. F. Stormer, Christiania, Norway.

Amalgam-washing device; amalgam drawn off into washing vessel, containing a skeleton drum, formed of side discs connected by a series of rods. As drum revolves, amalgam is carried up by rods and exposed in thin film to solvent.

May increase surface by placing open-mesh metal cloth around rods or weaving it through them.

627,193. June 20, 1899; J. F. Kelly, Pittsfield, Mass.

Amalgam-washing device. Amalgam circulates through chamber having carbon sides. Carbon sides, in electrical contact with amalgam, hasten oxidation and do not affect color of caustic.

631,468. August 22, 1889; C. Kellner, Vienna, Austria-Hungary.

Electrode in oxidizing cell, and a short circuit between amalgam and such electrode, such short circuit constituting a part of the return line of the main circuit.

In this construction the current derived from oxidation of the sodium is opposed to main current, and oxidation of mercury is avoided.

630,234. November 7, 1899; E. Baker, Winchester, Mass.

Mercury cathode flows in tortuous channel between low partitions which support the anodes. The discharge pipe is U shaped, and rises outside the cell to such height above the mercury within as will counterbalance the electrolyte, thus forming effective seal.

Oxidizing cell contains relatively deep layer of amalgam, which is thereby permitted to stratify. Flow of lighter amalgam is further retarded by inclined dams, imperforate at top.

645,055. March 13, 1900; H. S. Anderson, Springfield, Mass.

Mercury has tortuous flow in both decomposing and oxidizing cells, but latter is at higher level than former and amalgam is forced up by centrifugal pump. The barrel of this pump is perforated at such level that, in case pump works too rapidly, mercury will overflow, but electrolyte will not be pumped into oxidizing cell.

646,313. March 27, 1900; B. E. F. Rhodin, Sault Ste. Marie, Can.

Apparatus generally similar to 608,300, except that anode tubes are closed at upper end by inclined diaphragms, and anodes consist of crude copper in sodium sulphate solution.

Copper sulphate formed in anode compartment and sodium amalgam at cathode.

Ribs under mercury are inclined to radii, whereby the motion of anode bell causes amalgam to work outward toward periphery. After oxidation occurs the heavier mercury flows back toward center and under anodes.

652,761. July 3, 1900; J. B. Entz, Philadelphia, Pa.

In cell of Castner type affects circulations of the mercury by means of magnetic field.

659,655. October 16, 1900; E. Edser, London, Eng.

Cell divided into two or more compartments by one or more vertical partitions consisting of superposed V-shaped troughs of glass, or metal partly covered with mica, each trough containing sufficient mercury to cover the lower edge of the trough above. Brine electrolyzed in one compartment by a current passing from a carbon anode to the mercury in the troughs. The deposited sodium diffuses through the mercury to the other side of the partition, where it is oxidized by water, which fills the second compartment. The electrolyzing compartment is covered by a removable hood with outlet for chlorine, the lower edge of which extends into a mercury seal, a layer of vaseline or oil on the mercury protecting it from chlorine. To facilitate oxidation of sodium, places iron wire-gauze cathode in water compartment, and either short circuits it to mercury in troughs or connects terminals of dynamo to the carbon anode and iron cathode, the mercury acting as a bipolar electrode. In the latter case, interposes a resistance wire between the mercury and iron cathode to direct more current through the brine than the water. The vertical partition may be flat or annular. May employ a horizontal or an inclined partition with troughs of ⌣⌢ section, the lower edge of each dipping into mercury held in the next.

661,188. November 6, 1900; A. Nettl, Prague, Austria.

Cathode consists of a number of fine streams of mercury, flowing through holes or nozzles in the bottom of a supply vessel down through the brine, between carbon anodes. The sodium amalgam collecting at the bottom of the cell is protected from the brine by a layer of chloroform or carbon disulphide, lying upon the amalgam. Jets of mercury may be forced through the brine from below, in any desired direction, instead of allowing it to drop vertically.

673,754. May 7, 1901; G. and G. W. Bell, Liverpool, Eng.

General construction that of Castner cell, with two electrolyzing chambers and an intermediate oxidizing chamber. Causes the mercury to reciprocate between the chambers by first closing the chlorine outlet of the electrolyzing chamber, until the pressure of accumulated chlorine, acting on surface of brine, forces amalgam into oxidizing chamber, and, then, after a suitable interval for oxidation, opening chlorine outlet and allowing depleted mercury to flow back. Chlorine outlet may

be automatically controlled by a hydraulic timing device, or an electric motor meter in main circuit, or clockwork. May also force amalgam into oxidizing chamber by automatically raising level of brine in electrolyzing chamber, and then lowering level to permit mercury to flow back.

674,927. May 28, 1901; M. Mauran, Niagara Falls, N. Y.

Cathode for the oxidizing chamber of Castner cell used at Niagara, consisting of a series of parallel wrought-iron bars connected at the ends by cast-lead blocks.

674,930. May 28, 1901; M. Mauran, Niagara Falls, N. Y.

Adjustable knife-edge supports for Castner cell used at Niagara, and ball-and-socket connection to pitman which rocks cell.

674,931 and 674,933. May 28, 1901; M. Mauran, Niagara Falls, N. Y.

Anodes for the Castner cells used at Niagara, consisting of carbon bars having horizontal flanges at each side to extend over the mercury cathode, the flanges being slitted to facilitate escape of chlorine. Terminals consist of copper-plated carbon plugs, driven into recesses in upper portion of anode and connected by zigzag lead strips soldered to plugs. Upper portions of anodes extend through slots in cell cover and are surrounded by Portland cement.

674,932. May 28, 1901; M. Mauran, Niagara Falls, N. Y.

T-shaped pipe for removing gas from tilting Castner cell used at Niagara. Two branches of pipe extend into two gas-producing chambers and the third leads into gas main.

674,934. May 28, 1901; M. Mauran, Niagara Falls, N. Y.

Cathode for oxidizing chamber of Castner cell used at Niagara, consisting of a series of thin, parallel wrought-iron bars, each bent upward at right angles at both ends, with the free ends again bent at right angles to give horizontal terminals, which extend out of the cell.

678,851. July 23, 1901; H. S. Anderson, Springfield, Mass.

Interposes between mercury cathode and bottom of cell a thin, porous layer of pipe clay or pumice stone, which becomes saturated with brine, so that sodium is deposited on lower as well as upper surface of mercury. Porous layer may have a ridge extending into brine, with vertical openings to facilitate passage of brine into portions beneath mercury.

679,476. July 30, 1901; J. F. Kelly, Pittsfield, Mass.

Movable outer vessel contains layer of mercury and water. Electrolyzing chamber consists of fixed box with open bottom, within and extending down into mercury in outer vessel. Outer vessel reciprocated to bring new surfaces of mercury beneath brine and expose amalgam to water.

679,477. July 30, 1901; J. W. Kynaston, Liverpool, Eng.

Cathode consists of thin horizontal layers of mercury held in superposed non-conducting trays. Openings at alternate ends of trays cause mercury fed into upper tray to travel back and forth through series, amalgam escaping from bottom tray. Depth of mercury in each tray determined by a transverse ridge near discharge opening. Terminal wires touch mercury in each tray. Carbon anode may be placed between two vertical sets of trays.

680,440. August 13, 1901; B. E. F. Rhodin, Sault Ste. Marie, Can.

Stationary horizontal pan contains layer of mercury and water. Electrolyzing chamber rotates on vertical axis within pan and consists of a series of radial anode compartments of vitrified earthenware, the sides of which extend down into the mercury. A central cup has radial ducts, which serve to distribute brine into each anode compartment.

680,441. August 13, 1901; B. E. F. Rhodin, Sault Ste. Marie, Can.

Anode for cell of patent No. 680,440, consisting of a supporting block of carbon having vertical threaded openings through which pass threaded carbon rods, construction permitting adjustment and renewal of rods.

692,531. February 4, 1902; E. A. Le Sueur, Rumford Falls, Me.

Outer iron cathode vessel, filled with water, receives electrolyzing chamber, a wooden cement-lined frame closed below by horizontal amalgamated wire gauze, the mercury acting as a bipolar electrode. A layer of gravel may rest on wire gauze. Level of brine in electrolyzing chamber somewhat lower than that of water outside, to give equal pressure on both sides of amalgamated gauze. A plurality of anodes, each consisting of platinum filaments radiating from a central stem, sealed in a glass tube. May connect cathode terminal directly to wire gauze.

693,678. February 18, 1902; G. M. Wilson, Sault Ste. Marie, Can.

Side passages carry amalgam from electrolyzing chamber into oxidizing chamber. Horizontal paddle wheel sweeps depleted mercury back over a dam and beneath vertical partition into electrolyzing chamber. Provides feed and overflow pipes in each chamber.

695,302. March 11, 1902; J. D. Gilmour, Glasgow, Scotland.

Electrolyzing chamber with carbon anodes and mercury cathode, placed within oxidizing chamber. Two series of short pipes extend from the lower portion of the outer chamber into and slightly above the bottom of the inner chamber. The outer vessel contains a layer of mercury and is filled with water. A pump continuously varies the pressure of the water and forces mercury up through one set of pipes into the electrolyzing chamber, while the amalgam flows out through the other set into the electrolyzing chamber. The caustic liquor overflows from the outer vessel at each pulsation of the pump.

699,401. May 6, 1902; C. J. Reed, Philadelphia, Pa.

In order to fully oxidize the sodium contained in a bipolar mercury electrode without oxidizing the mercury, and at the same time utilize the resulting current, employs a greater number of electrolyzing chambers than oxidizing chambers, and thereby causes the amalgam in each oxidizing chamber to contain sufficient sodium to transmit the entire current. The cathode of each electrolyzing cell consists of a series of amalgamated copper discs rotating on a horizontal axis and provided with curved grooves to distribute mercury, into which the lower edge of each disc dips, evenly over their faces. A carbon-plate anode depends between each pair of discs. In order to convey the depleted mercury from an oxidizing chamber to the next electrolyzing chamber without permitting the electric current to flow, uses a non-conducting transfer wheel with a series of pockets, which dip up and deliver the mercury in separate globules.

699,415. May 6, 1902; C. J. Reed, Philadelphia, Pa.

The electrolytic cell has in its bottom a plurality of parallel pockets filled with mercury. An amalgamated sheet-metal cathode is arranged over each pocket, being either a plate with means for vertically reciprocating it into and out of the pocket, or a disc carried by a horizontal revolvable shaft, with its lower edge depending into the mercury. The disc has curved grooves, which assist in taking up the mercury and distributing it over the surface of the disc. A carbon anode, which may be surrounded by a porous cup, depends between each pair of cathodes. The amalgam in the pockets is removed and replaced by mercury, as desired. The amalgam may be carried from the electrolytic cell into an oxidizing cell of similar construction, and the depleted mercury may then be delivered to a second set of electrolytic cells by a rotating transfer wheel having a series of pockets, which dip up and deliver the mercury in separate globules.

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## SAULT STE. MARIE.

The opening of the hydro-electric plant of the Michigan Lake Superior Co., at Sault Ste. Marie, which is exceeded in size only by that at Niagara Falls, marks a new epoch in the development of this young industrial center. Under the energetic management of the Clergue Syndicate, the development of the Canadian "Soo" has been rapid in recent years. Now, after the opening of the Michigan power house, the development of the American side promises to be not less impressive. Nor should there be any doubt that the development of the "Soo" in the future will be closely allied with the advance of electrochemical industries.

Perhaps the most important condition which determined the general engineering features of the new power plant was the low available head of only 20 feet. It necessitated the installation of a great many generating units of comparatively small size. The total capacity of the power house is 32,000 kilowatts, in 80 units of 400 kilowatts each. This large number of small units accounts for the enormous size of the plant.

We publish in this issue an interesting article by Dr. J. W. Richards, on the present industrial conditions of the "Soo" and on the outlook for the future, especially with respect to electrochemical industries. The main reason why one may safely prophesy that the development of the "Soo" will be closely allied with electrochemical enterprise is the fact that the distance of Sault Ste. Marie from any large city is too great to justify transmission of power. The power generated there is to be consumed at the spot. The location is very favorable for cheap transportation of the goods, either by water or on railways. The conditions are therefore fulfilled which should enable the "Soo" to become an important industrial center, like Niagara Falls. In fact, the marvelous development of the "Soo" in the last few years leaves no doubt concerning the future. Electrochemical industries have already participated in this development. There is the alkali plant, using the Rhodin process, which, however, is not in operation at present. For the manufacture of calcium carbide, a large amount of the power of the new power house has already been contracted for. And last, but not least, there are very promising prospects for developments in the electrometallurgical line, especially for the treatment of Lake Superior copper and Sudbury nickel.

It is perhaps superfluous to remark that electrochemical plants, with their uniform continuous load and their very high load factor, are the ideal customers for a great power plant, and that therefore the managers of power plants are fully justified in making special inducements to electrochemical enterprise. We wish great success to the energetic managers of the enterprise at Sault Ste. Marie, and we trust that in future we may often have to record advances of electrochemistry and electrometallurgy at the "Soo."

## LOW TEMPERATURE RESEARCHES.

We need offer no apology for devoting much space this month to the publication, nearly in full, of Prof. James Dewar's presidential address to the British Association on this subject, which, although not directly electrochemical, is of the highest interest, as it refers to a field on which very little is yet known and which may become of great importance in the future. Professor Dewar's extended researches in this field render his address an authoritative statement of our present knowledge in this line.

Electrochemical processes, as far as they are not performed at ordinary temperatures, have up to the present been essentially high temperature processes. The electrical furnace is the ideal means of producing high temperatures, which are, indeed, limited only by the difficulty of finding sufficiently refractory materials for the furnace walls. Electric furnace researches have given us a new chemistry—that of high temperatures—and these researches have already brought many fruitful industrial results. There is great difficulty in these researches, in so far as it seems impossible at present to predict what one will get in such a process. In fact, a very prominent investigator and pioneer in this line once stated in a private conversation that it is impossible to work according to a clearly predetermined plan; the only way is to put materials into the furnace, turn on the current and wait to see what one will get. This may seem a rough and unscientific way, but it nevertheless states correctly the limits of our present knowledge.

There is, indeed, a remarkable difference between the chemistry at high and at low temperatures. Prof. J. H. van't Hoff has emphasized this difference in one of his lectures on physical chemistry, held at the celebration of the tenth anniversary of the University of Chicago last year, while discussing Berthelot's "principe du travail maximum." This principle is very simple. It states that the amount of heat which a chemical action evolves indicates at the same time in which direction the reaction will occur. If there is a possibility of the evolution of heat by means of a chemical reaction, this reaction, and not the reverse, will take place. Indeed, this principle is correct in a great many instances, and is a very useful means to predict, under normal conditions, what will happen. But there are cases where the actual facts clearly contradict this law. Professor van't Hoff points out that when one considers this matter from the point of view of the second principle of thermodynamics, then Berthelot's principle appears to be correct at temperatures near the absolute zero point. That Berthelot's principle is found to agree with so many observations in ordinary chemistry is simply a result of the fact that at the ordinary temperature of chemical experiments we are relatively near the absolute zero of temperature. At 1,000° Celsius the processes occur in a quite different manner, and often in a way which is opposite to Berthelot's principle. The lower the temperature the better we are able to predict things by means of Berthelot's principle. Whether the low temperature researches will have important industrial results can only be borne out by the development of the future, but it must be said that it is quite likely that this will be the case

## FARADAY'S LAW AND THE THEORY OF ELECTRONS.

In this issue we publish an article on this subject which we believe may be of interest to the practical electrochemical engineer. The modern hypothesis of electrons is usually regarded to be of theoretical value only, and practical men are somewhat inclined to scorn it. In the article to which we refer an attempt is made to show that this hypothesis ought to be useful to the practical man, as it offers a very simple and safe means of applying Faraday's law, which should certainly not be despised, as it is surprising to see how often mistakes are made in numerical applications of this fundamental law of electrolytic action.

Most electrochemical text-books state Faraday's law either in too vague or too narrow a sense. We say "too vague," as very often this law is given more qualitatively than quantitively. But what the engineer needs is an exact, concise method by which he can calculate numerically in any case the theoretical output in pounds or kilograms per ampère hour. The law is also given in too narrow a sense, by stating merely the relation between the ampère hours and the weight of ions "liberated at the electrodes." One, then, cannot apply it to cases in which no ions are liberated, but where there is a simple change of valence, as at the carbon electrode in the Bunsen cell or in the chromium cell. It is indeed difficult to give briefly a complete and concise statement of Faraday's law, and it is much easier to form a mechanical model or image suitable for all cases and based upon the hypothesis of ions and electrons. Of course, if such a hypothesis is useful for such purposes, this should not be taken as a proof of the complete correctness of the hypothesis, and one should bear in mind that the use of such mechanical models is comparable to using crutches in walking. But it is certainly better to reach a goal safely by means of crutches than not to reach it at all.

It is interesting to note how closely Professor Johnson's notation of "bonds," which was based purely on chemical considerations, applies to electrochemical problems if only positive and negative bonds are considered as positive and negative electrons. This is an example showing that in natural science there are many ways by which one may approach a certain goal, but the final result must always be the same if it is to represent the truth. Yet the same truth may be expressed in different ways or by different images, according to the point of view from which one looks at it.

## STORAGE BATTERY INVENTION.

In this issue we publish an article by Prof. A. L. Marsh, on the thallium storage cell, which is quite interesting in several respects from a scientific point of view, although, as the author states, it is unsuitable for the purposes of the practice. The principal reason why this cell must fail in practice is that the electrodes are not insoluble in all states of charge and discharge. From the experience of a great number of inventors, who for a long series of years have made extended experiments and trials with new storage batteries, it seems safe to conclude that the solubility of an electrode in any state of charge or discharge is fatal to the commercial success of the

battery. It is worth while to discuss this point somewhat in detail.

There are two reasons which may cause the failure of a battery due to solubility of an electrode. The first refers only to batteries with electrodes of two metals. For instance, should in a zinc-copper cell with an alkaline electrolyte copper go into solution, the copper ions will go to the zinc electrode during charge, and will be deposited on the zinc; this copper deposited on the zinc will form, together with the zinc, a short-circuited couple, and zinc will be dissolved, the total chemical energy lost being changed into Joulean heat. In its result this is equivalent with local action. In the same battery zinc goes into solution, but it is not deposited on the copper; hence there is here not the same disadvantage inherent in the solubility of the zinc as in the solubility of the copper. From this the rule results which has been recognized as correct for years—that in a storage battery with electrodes of two different metals the electrode, which is the cathode during discharge (or the anode during charge), should be insoluble in any state of charge or discharge. Of course, this rule has no effect on the thallium cell, because thallium is the only metal used in this cell.

The second reason why no soluble electrodes should be used is of universal importance, and is pointed out clearly by Professor Marsh when he speaks of the difficulties of obtaining compact, evenly-distributed and adherent deposits. The experience of electroplaters proves that to get good adherent deposits of any metal special conditions must be carefully observed. It is evident that this is strictly impossible in storage-battery practice. Hence during charge there will always occur deposits in spongy or not adherent form, and this will result in short circuits. This has been proven conclusively by the trials which have been made with the zinc-lead peroxide accumulator, which has otherwise distinct advantages over the ordinary lead cell.

The rule that a storage cell should not contain any soluble electrode is fulfilled in the lead cell, and is claimed to be fulfilled in the Edison iron-nickel accumulator, which may be considered at present as the most promising rival of the lead cell. Edison's iron-nickel cell has just this advantage of the unsolubility of the electrodes over the old Edison-Lalande cell. While the thallium cell—or the general type of which it is a special case—has certainly distinct interesting features, which are clearly brought out by Professor Marsh, there cannot be any doubt that neither this cell nor any other cell of the same type is applicable for commercial work.

## CAUSTIC SODA BY THE DIAPHRAGM PROCESS.

In the first two issues of this journal we published, in the Digest of United States Patents, prepared by Messrs. E. A. Byrnes and C. P. Townsend, a complete review of the patents referring to the electrolysis of sodium chloride with mercury cathodes. We commented editorially in our last issue upon an important point in connection with this class of processes. In our present issue we publish the first part of the review of the patents referring to diaphragm processes.

It is a chemical commonplace that the rate of chemical change is proportional to the active mass of the reacting substances, and that the only chemical changes which are truly complete are those in which one at least of the final products assumes a physical condition which withdraws it from the sphere of reaction. This mass law has its direct applications to electrolytic work, but, without following them too closely, it may be remarked that in general the electrolytic methods which work at high efficiency are those in which one at least of the products passes into an insoluble state, or is otherwise withdrawn from the field of electrolytic action. If the physical character of the resultant product, primary or secondary, is such as to insure its isolation, the efficiency will be high.

It so happens, however, that many of the most important industrial electrolytic products are soluble in their electrolytes, either directly or by reaction therewith, and it is around such that the most formidable difficulties cluster. Since they are not isolated by virtue of their physical state, it is essential that means be provided for shielding them from the influence of the current and of the electrolyte, and from this necessity has arisen the type of diaphragm cells.

Caustic soda occupies the peak of the trouble line. If the metal sodium be absorbed by a mercury cathode, and by it carried from the region of reaction, the field is left clear and the efficiency is high. If, however, it be permitted to oxydize at the cathode, the efficiency will depend directly upon the effectiveness of the means employed for the restriction of the caustic solution to this point. For this reason, and because, to an investigator, failure has much the same value as success, provided only the causes be recognized, there is no more suggestive field for study than the efforts, past and present, to compass the direct conversion of brine into caustic.

## ELECTROCHEMICAL TERMINOLOGY.

The Standardization Committee of the American Institute of Electrical Engineers has done excellent work in standardizing methods of testing and paving the way towards the use of a uniform terminology in electrical engineering. We hope the American Electrochemical Society will undertake the same task for industrial and scientific electrochemistry, for it cannot be denied that at present a great confusion prevails in electrochemical terminology. We may only call attention to the different sense in which the terms positive and negative plate of an accumulator are used. In scientific electrochemistry a great deal of very valuable work has been done in Germany, but it must be said that the terminology introduced by the Germans is often misleading, and often, when the German terms are correct, the translation is wrong. For instance, Kohlrausch's "Beweglichkeit" of an ion is usually translated as ionic speed or velocity, which is simply wrong, because the dimensions are not those of a velocity. Finally, the notification in books on electrochemistry should be simplified; it should agree with that generally used by electrical engineers.

Electrochemical engineers and scientists should remember that they are workers in the same field, and the American Electrochemical Society should use their authority to bring about uniformity of terms and notation.

## THE OPENING OF THE WATER WORKS POWER PLANT AT SAULT STE. MARIE, MICHIGAN.

At noon, October 25th, occurred the formal opening of the water-power plant of the Michigan Lake Superior Power Co. at Sault Ste Marie, Mich. The event is an important one, not only to the citizens of that locality, but to the electrochemical industry in general, because it marks the beginning of operation of the second largest water-power electric plant in this country. All of the important features of the hydraulic installation at this place are described in the article by Dr. J. W. Richards on another page of this issue.

Mr. H. von Schon has been chief engineer of the undertaking. Mr. W. Owen Thomas is electrical engineer in charge of the electrical work, and designed many of the interesting electrical features.

At the present time the market for the company's electrical output is practically undeveloped at the Soo, and there is abundant power for industries desiring cheap electrical power. The investment in the completed plant will be, it is announced, about $4,000,000, or $135 per kilowatt. This is not high as investments in water plants run, and the company ought to be able to make a very low rate.

At the formal opening, on October 25th, shortly after noon, Chief Engineer von Schon spoke a few introductory words. Mr. F. H. Clergue, the head of the whole enterprise, answered briefly, and Miss Helen Clergue then stepped forward and, by closing the switch, set the machinery in motion.

A banquet on the evening of October 27th closed the festivities.

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## ELECTROCHEMICAL UNITS.

In our last issue (page 60) we published a longer abstract of Mr. Alfred H. Cowles' interesting American Electrochemical Society paper, in which he proposes a new system of electrochemical units, based upon the following very simple relation found by him: 100 ampères liberate one cubic meter of hydrogen in one day. We are indebted to Mr. Cowles for the following additional information:

Based upon this relation, he proposes that this quantity of electricity be called a kilocrith col, as the weight of a cubic meter of hydrogen is a kilocrith, or 1,000 criths. The calculation from which the foregoing agreement is found can be made from the following data: In the "Smithsonian Contributions to Knowledge" for 1896 is printed Dr. Edward W. Morley's classic paper on the atomic weights of oxygen and hydrogen. In the same he gives the weight of a crith, or one cubic decimeter of hydrogen, as .089873 = .000027 grams at 0° C., 45° Lat, and at the mean atmospheric pressure at sea level. If the atomic weight of hydrogen be taken as one, we must then attribute an atomic weight of 107.11 to silver, and, taking Lord Rayleigh's determination of the electrochemical equivalent of silver, .001118 grams per coulomb, the electrochemical equivalent of hydrogen becomes .00001043786 grams. Under these premises, the kilocrith col, or 100 international ampères, for one siderial day liberate 1.00071 cubic meters of hydrogen under normal conditions. Of course, this can be reduced to a crith col by dividing in each case by 1,000, in which case we have the electric quantity that will free a crith or liter of hydrogen.

We may use this opportunity to correct a typographical error which occurred in our abstract in the last issue, where, in stating the above relation, one cc. was said, instead of one cubicmeter. The two remarkable relations found by Mr. Cowles are exactly stated, as follows: First, 500 ampères in one solar day decompose practically (within ½ per cent.) one pound (avoirdupois) molecule of any univalent compound; and, second, 100 ampères in one siderial day liberate one (exactly, 1.00071, from the best available figures) cubic meter of hydrogen under normal conditions.

## DEVELOPMENTS IN ELECTROMETALLURGY OF IRON AND STEEL.

An interesting paper on this subject, which appears to become of commercial importance, was read at the Niagara meeting of the American Electrochemical Society, by Marcus Ruthenberg. It is well known that many iron ores occur throughout the world, which are too low in tenure to permit smelting. If the iron in these ores occurs as magnetite $Fe_3O_4$, it permits of a concentration by means of magnetic separators. Magnetites occur but seldom of such purity that they are entirely free from sulphur and phosphorus, and it depends very largely upon what portion of the ore these two metals are associated with, as to the fineness to which the ore must be ground, and its particular treatment in the magnetic machines. It is found that when ores are ground finely and an attempt is made to magnetically concentrate them dry, there is a measure of adhesion between the particles of magnetic and non-magnetic portions that will not permit of cleanly work; this is obviated by handling the ground ore in water, in which case the water seems to lubricate the particles so that the magnetic portions come away cleanly. A clean, fine, blue-black powder is thus obtained which may go anywhere from 65 to 72 per cent. of magnetic iron, pure peroxide being 72.40. It then becomes a question as to how this iron ore may be handled in a furnace. The author discusses critically several methods which can be used and have been suggested for this purpose. He then describes an entirely new method which he has had in use for upwards of a year.

This method consists in taking the concentrates cleaned up to the highest point of possible purity, and putting them through an electric furnace, the melting zone of which is a magnetic field. The ore being magnetic, and the polar projections of this magnetic field being at the same time the electrodes of the smelting circuit, the magnetic bridge thus formed by the ore forms a high resistance in the smelting circuit. The heat of the smelting circuit is engendered within this bridge of ore itself. The electrodes are water-cooled. The moment that the ore melts it loses its magnetism, and gathering weight from new molten material being added to it, it falls out of the magnetic field, its place being taken by fresh portions of ore from above. The result of this operation is agglomerated, coherent masses, ranging in size from a bean to a walnut, that are hard, strong, tough and porous, differing in analysis in no way from the ore prior to its agglomeration except for the absence of moisture and the last traces of sulphur. The product is in an ideal condition for use in the blast furnace.

If reducing material, such as powdered coke dust or charcoal dust be added to the charge prior to its introduction to the electric furnace, a partial reduction takes place and the fritted mass of carbonaceous dust and iron ore, partially reduced, is dropped into a soaking pit. If allowed to remain in this soaking pit a proper length of time, cementation takes place through the action of the heat left in the ore, by the electric furnace, and the action of the carbon fritted into the mass, which results in producing reduced metal, which may be properly termed steel. This material from the soaking pits is ideal for melting in the open-hearth furnace. It thus becomes possible to produce first-class steel direct from the ore, through the intermediation of the electric furnace and the soaking pit, producing spongy iron or steel ready for immediate melting in the open hearth, without the intervention of the blast furnace in any part.

The author believes that this process could be used to great advantage for many low-grade ores. He especially refers to ferruginous beach sands which occur in many parts of the world, notably on the St. Lawrence River and on the Pacific Coast.

For further details, the reader must be referred to the full paper, published in the "Transactions" of the Society, which will come out at the end of this month.

## ELECTROCHEMISTRY AT SAULT SAINTE MARIE.

By JOSEPH W. RICHARDS,
*President of the American Electrochemical Society.*

A DESCRIPTION kept conscientiously within the above title would be very brief. It would cover a description of the Rhodin process of manufacturing caustic alkali and bleaching powder and would then stop, for that is the only electrochemical process at present installed at "the Soo." With the indulgence of the reader, we will therefore digress from the straight and narrow way and use the above title as a text under which we will speak of the general situation of Sault Ste. Marie, its facilities for manufacturing and its potentialities in the electrochemical line.

First, as to the power there available, the St. Mary River is the outlet of Lake Superior, which, with its 30,000 square miles of surface, is the largest body of fresh water on the earth. The river runs over rapids about half a mile long, with a total fall of 20 feet. This head is made available by constructing canals around the rapids, and thus conducting the water to power houses below them. The discharge varies with the season and the winds, but is, at its lowest, 3,000,000 cubic feet per minute, representing a total of 135,000 horse-power. This is however to be diminished by the loss in conversion into mechanical and electric power, and by the fact that in order to give flow through the intake canals, some of the head must be sacrificed, and only 18 feet of head can be counted on at the power houses. Allowing for these, the minimum available electric power of Sault Ste. Marie is about 110,000 horse-power. More than this might be generated at times, but it will hardly pay to install a power plant in excess of this, part of which would either be idle or run at only a fraction of its capacity for part of the year.

The present utilization of the power includes a 20,000 horse-power house on the Canadian side, owned by the Lake Superior Power Co., and a 40,000 horse-power plant on the American side, owned by the Michigan Lake Superior Power Co., so that 60,000 of the possible 110,000 horse-power is already taken care of.

The American plant has just been completed. The water-power canal is over two miles long, and traverses the city of Sault Ste. Marie, Mich. It is 200 feet wide, 25 to 27 feet deep, cut partly through red sandstone rock and partly through red clay, and will be capable of delivering some 20,000 cubic feet of water per second. It was an expensive canal to construct, the bottom being in places planked over to avoid scouring, and eight steel bridges being necessary where it crossed streets. The power house is on the river edge, and is 1,340 feet long, 87 feet wide and 107 feet high, built in a most substantial manner of sandstone, on pile foundations. It is divided into 80 divisions, to each of which is a set of four 125 horse-power turbine wheels, actuating a 500 horse-power dynamo on the floor above. Current for near-by industries will be generated at low voltage and of the amperage needed; for distant use it will be transmitted at high voltage. The canal cost $3,000,000, the power house, with docks and equipment, $1,000,000, making a total cost of $4,000,000. If we estimate the interest which this money should earn at 10 per cent., the cost of maintenance and labor at 2½ per cent. and depreciation at 2½ per cent., the price which this power should command, as electrical horse-power, is about $15 per horse-power per year. The statements are made officially that industries which contract for this power at $20 per horse-power per year will be furnished sites free, and will be exempted from borough taxation for five years, but unofficial statements are current to the effect that some of this power may be had for prices nearer to $10 per horse power per year than $20.

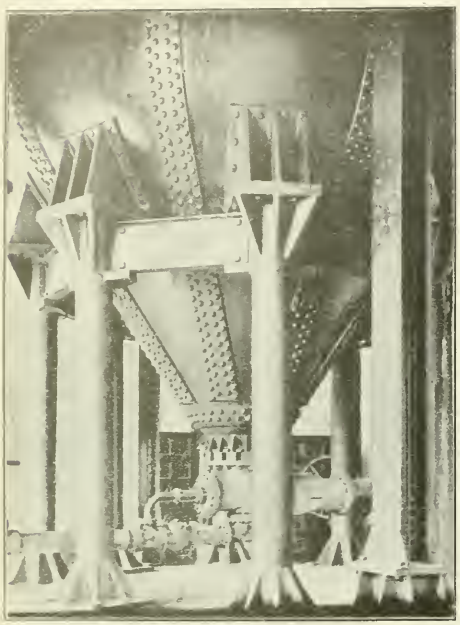
GENERAL VIEW OF THE CANADIAN SIDE

Showing from the left to the right the Canadian Electrolytic Alkali Co. the power house, wood pulp mill, sulphite pulp mill, iron foundry and office building.

The Canadian plant is situated alongside of the Canadian lock and, with a 100-foot wide canal, is generating at present 20,000 horse-power. This power is almost all in use, the larger part being taken by the Sault Ste. Marie Pulp and Paper Co., who have the largest ground wood pulp mill in the world, having a capacity of 150 tons of dry pulp and 75 tons of bleached sulphite pulp per day. An interesting combination is the installation of a roasting plant to roast nickel ores from the company's nickel mines at Sudbury. This is placed alongside the wood pulp mill, and the sulphur dioxide gas generated by roasting the ore is passed directly to the pulp mill and there used for bleaching and gelatinizing the pulp in connection with

the lime bisulphite. An iron foundry and a large machine shop use also considerable power. The power plant and buildings are fairly and substantially built, and there is plenty of land in the vicinity for new industries.

About a mile further up the river is a new steel plant, con-



DIGESTER, SULPHITE PULP MILL.
65 ft. high, 17 ft. diameter.

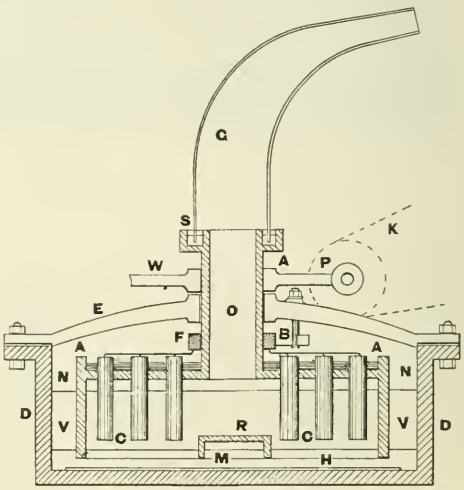
sisting of a large plant of charcoal by-product ovens for obtaining charcoal from hardwood and saving the acetic acid and wood spirit, two blast furnaces—one for making charcoal iron, the other to use coke—and a Bessemer steel mill, with a capacity of 600 tons per day. At these mills the first steel rails rolled in Canada were made, and, since the Canadian Government pays a bounty of $3 per ton on all pig iron made from ore mined in Canada, and an additional bounty of $5 per ton on all steel made in Canada, there should be no doubt as to the profitable operation of this modern plant.

The Rhodin process for making caustic alkali is the only electrochemical process now located at Sault Ste. Marie, and we will describe it at length. Before doing so, however, we will note the statements which are made that 10,000 horse-power on the American side is already contracted for, for the manufacture of calcium carbide, by the Union Carbide Co., and 5,000 horse-power for extensions of the Rhodin process; while it is further contemplated to establish electrolytic plants for refining Lake Superior copper and Sudbury nickel. It is possible that some of these propositions will materialize. Calcium carbide is in very extensive use in Western Canada, as was observed by the writer on a recent trip from Victoria, B. C. The consumption of this chemical is bound to increase largely, as the acetylene light is so well suited to the conditions prevailing in that vast territory. Lake Superior copper can be refined in transit towards the Eastern markets very advantageously at this point, and the same applies to the Sudbury nickel. It is true that navigation is closed for five months of the year, but the railways centering there have given through freight rates to Chicago and other points, which are so low as to practically annul this disadvantage and make the railway transportation as cheap as the water rates all the year around. This statement was made to the writer by Mr. F. J. Clerque, general manager of the Clerque Syndicate, and is therefore official.

The Canadian Electrochemical Co., Ltd., rent power from the Lake Superior Power Co., on the Ontario side, and are installed in buildings owned by that company, close to the Canadian lock. They use the Rhodin process of electrolyzing sodium chloride solution and obtaining caustic soda and bleaching powder. When visited by the writer, September 12th last, they were not in operation, because the war between the chemical and electrochemical alkali companies in Europe had so demoralized the market for the products (bleaching powder being sold by them in Canada as low as $20 per ton) that the plant could not be operated profitably at the low prices.

The installation to be described was considered by the company as a more or less experimental one, which would develop into a large plant on the American side. But while the power for the latter has been contracted for, the company have been unable to take any steps towards erecting that plant, because of financial difficulties, too little of the capital stock of the company having been realized as available cash for erecting the plant. It is hoped that a financial reorganization of the company will enable the American plant to be commenced in the near future.

The Canadian plant consists of three 350 horse-power turbines, each actuating a 200-kilowatt dynamo. Each dynamo runs a row of 40 decomposing cells, connected in series. The current in one circuit is 900 ampères, and the total potential at the dynamo is 220 volts, which, allowing the extra 20 volts for the resistance of the conductors and connections in the circuit, leaves an average drop of 5 volts per cell. The theory of the action of the cell is the decomposition of concentrated brine between graphite anodes and a layer of mercury in a large iron pan as cathode, the anodes being contained in a bell-shaped vessel, which collects and carries away the evolved chlorine, while the mercury charged with sodium escapes under the lip of the bell and passes into the space outside, where, coming




RHODIN CELL.

into contact with water, it discharges its sodium and produces caustic alkali solution. Mechanical arrangements produce a rotation of the bell, the continuous inflow and outflow of brine therefrom and a continuous or intermittent supply of water to the pan outside the bell.

The annexed diagram of the cross section of the cell shows the mechanical details. D is the cast-iron pan, 5 feet in diameter by 1 foot deep, containing a layer of mercury, H, which can scarcely be less than 1 inch in depth, which would imply at least 1,000 pounds weight of mercury in each cell, costing, at current prices, $500. This item will then constitute one of the largest items of cost of the plant. Suspended inside this pan is an inverted earthenware bell, A, 3 feet in diameter, through the top of which pass the graphite anodes, C, which reach down to within 1 inch of the mercury. These carbons are fastened into the holes by pouring cement around them, and are in electrical connection with the copper ring, F, to which the current is conducted by a brush, B.

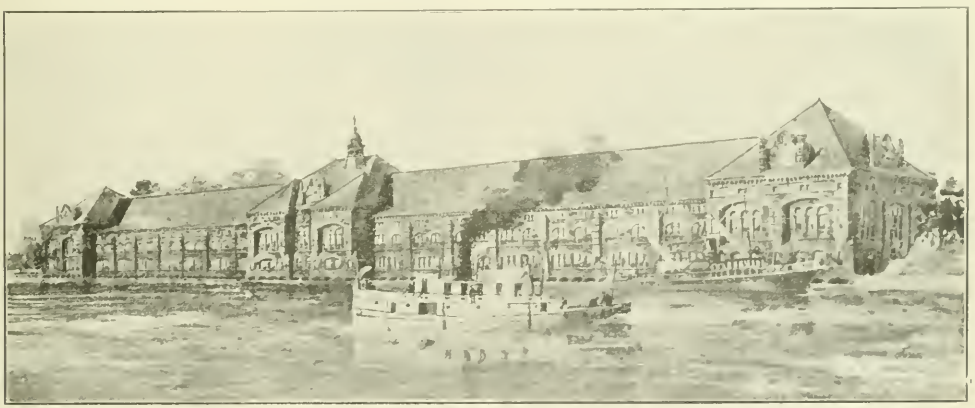
The inside of the bell, sealed off from the outside by its edge dipping beneath the mercury, is partly filled with concentrated brine solution. This is renewed continuously by inlet and overflow outlet pipes passing through the botom of the pan. The fresh brine is fed directly into the field of decomposition, between the carbons and the mercury. The bell is supported by a framework across the top of the iron cell, and has an upward prolongation or tube through which the chlorine escapes. To make connection with the stationary chlorine pipe, the latter dips into a circular water-seal on top of the prolongation, as shown in the cut at S. The bell is rotated by a worm and gear, thus bringing the carbon anodes continually over fresh surfaces of mercury. The brine is thus given a rotary movement also, which further imparts itself to the mercury, and the latter, by means of radial grooves in the bottom of the iron pan, is by that means continually forced towards the outer edge of the pan.

Outside of the bell there is water resting upon the mercury, which acts upon the amalgam and produces caustic soda, with liberation of hydrogen. This solution is allowed to stay until it becomes quite strong, and is then run off by a siphon pipe and replaced by fresh water. It was stated by the inventors that the iron pan was heated externally to nearly the boiling point of the solutions, resulting in preventing the brine keeping so much chlorine in solution and increasing the efficiency of discharge of the amalgam, as also reducing the electrical resistance of the cell. This information, however, was altogether at fault, for above 75 degrees chlorate is formed in large quantity, destroying the anodes and causing great danger of explosions from the admixture of oxygen with the chlorine. The real facts are that the passing of 900 ampères through such a cell, 3 feet in diameter, heats the liquid by its own resistance much more than is desirable, and the problem is rather how to keep the cell cool than to heat it.

The theoretical difference of potential required to decompose a saturated brine solution and to form sodium and set free chlorine is [illegible] = 4.22 volts. The absorption of the sodium to form amalgam, however, gives out considerable energy, which is returned as e. m. f. to the circuit; this amounts to [illegible] = 0.89 volt. The voltage absorbed in decomposition is therefore 3.33 volts. The actual voltage used to force 900 ampères through is 5 volts, which leaves, therefore, 1.67 volts absorbed in overcoming ohmic resistance, and represents electrical energy converted into heat. This is equivalent to a generation of about 45 pound calories of heat per minute in the apparatus, sufficient to heat it and its contents about 20° F. in an hour if no heat were radiated. We see that it is therefore quite likely that the apparatus will rush some 20° F. above the outside room temperature simply from the heating effect of the current.

In such an apparatus it is likely that there will be some loss by re-combination of sodium in the anode compartment. There is no positive removal of the amalgam from the bell, neither is there a positive method of discharging it outside. These two operations take place at their own pace, so to speak, and therefore will lag behind the charging action with such a heavy current. Mr. Rhodin has stated the loss by re-solution at the brine surface as 3 per cent. It might have been anticipated as still larger. The discharge is voltaic in its nature, for the iron pan and amalgam form a short-circuited voltaic couple, which, when moistened by the water, causes the discharge of the sodium and the evolution of hydrogen from the iron. This action differs from the Kellner method of discharging amalgam, in that the latter uses a distinct cathode plate in the caustic solution, separated from and not in physical contact with the amalgam, and thus constituting a galvanic cell, of which the amalgam is one pole and the wire from the cathode plate the other pole, and from which a useful galvanic current can be extracted and utilized, as Kellner utilizes it in his German patent, in assisting the main current used for decomposition in the cell or for any other exterior purpose.

With the voltaic couple action of Rhodin there is no usefully available e. m. f. generated, and the whole energy of decomposition of the amalgam, representing one-fifth of the whole current energy used in the apparatus, heats up the caustic soda solution, and thus increases the temperature of the apparatus. Using Kellner's or Castner's arrangements, whereby the galvanic e. m. f. of this cell is restored to the circuit, only as much of this energy is converted into heat in the caustic solution as is necessary to overcome the ohmic resistance between the cathode and anode in this solution,



MICHIGAN POWER BUILDING.

which, with properly-shaped cathodes, should be *less* than the galvanic e. m. f. of the cell.

The whole installation consists of 120 of these cells, but only 80 have been in operation at once. The bleaching-powder plant consists of 10 chambers, each 55 feet 6 inches long, 17 feet wide and 6 feet 6 inches high, made of No. 6 sheet lead, and with a 2-inch tile floor. The lime plant can furnish 14 tons of slaked lime daily. With 80 cells in operation, the output was 4.4 tons of bleaching powder and 2 tons of caustic daily. This represents about 80 per cent. of the theoretical output for the current used.

The salt used contained 99.5 per cent. of sodium chloride, the rest being mostly calcium and sodium sulphates. These and the free chlorine cause about 1-20 of 1 per cent. of mercury to go into the brine, but, as the solution is used over and over, this causes no loss, except when the brine is changed because of becoming impure, and then, every three or four weeks, about 20 pounds ($14 worth) is lost. In the alkali solution one pound of mercury (worth 70 cents) is dissolved for every 27,500 pounds of caustic produced. This loss is therefore negligible from a commercial standpoint.

If the whole 120 cells were operated, the 4 tons of caustic soda and 9 tons of bleaching powder which it would produce daily would supply all of the latter consumed in Canada and a considerable proportion of the former, but at present market prices in Canada, without a protective tariff, the plant cannot be profitably operated.

## THE THALLIUM STORAGE CELL.

By A. L. Marsh.

THE oxides of thallium are possessed of properties which place them in a new class of electrode materials. The lower oxide, thallous oxide ($Tl_2O$), is soluble in water, while the higher oxide, thallic oxide ($Tl_2O_3$), is insoluble in water and in potassium hydroxide solutions. No other metal forms oxides which bear to each other the above relations. Silver, perhaps, comes the nearest, but differs in that its lower oxide is only very slightly soluble in water.

Thallic oxide in a hydrated state is an almost black compound, resembling lead peroxide. It is a conductor of electricity, and is deposited on the anode from alkaline solutions, just as lead peroxide is deposited from a nitric acid solution. Thallous oxide, or rather the hydroxide (TlOH), is very soluble in water, and is a more stable compound than the thallic oxide. Metallic thallium can be readily deposited from its water solutions by the electric current. In ease of deposition, it stands near the metals lead and cadmium. Here we have the essential features of the thallium cell: For the negative, a metal which may be easily deposited from its water solutions; an electrolyte of thallous hydroxide (TlOH) which is the product of oxidation at the negative or reduction at the positive; and for the positive thallic oxide, an easily-reducible compound, a conductor of electricity, and capable of being deposited on the anode from an alkaline solution.

In charging a cell using a thallous oxide electrolyte, both the positive and the negative active materials are formed from the electrolyte, while on discharging the cell the process is reversed; the materials at both electrodes return to their original condition as electrolyte. There are only two oxides of thallium known, and these, together with the metallic condition, constitute the exact number of chemical changes necessary to the storage of electrical energy in the form of chemical energy in the so-called storage battery. Many metals, under a given set of conditions, are capable of a number of changes in excess of the required number, and therefore introduce complications.

Thallium was discovered in 1861 by Crookes, with the aid of the spectroscope. In examining some seleniferous flue dust from a sulphuric acid manufactory in the Hartz Mountains, Germany, a bright green line was discovered in the spectrum, and the new element was given the name thallium, which is derived from the Greek word meaning "green," or "a young shoot." The honor of having isolated the metal and establishing its true character belongs to Lamy.

The element occurs in small quantities, but is widely distributed in Spanish and Belgium pyrites. In some of these ores the quantity of thallium reaches as high as 3.5 per cent. It is also found in certain mineral waters, and in some specimens of mica and lepidolite. Mother liquor from zinc works in the Hartz Mountains contains about .05 per cent. of thallium. A rare Swedish mineral called Crookesite contains as high as 18 per cent. of this metal. Its chief source at present is the flue dust of sulphuric acid works.

The metallurgy of thallium is comparatively simple. The flue dust is extracted with water, and the thallium precipitated as thallous chloride (TlCl) with hydrochloric acid. This is dissolved in sulphuric acid, and from the resulting solution metallic thallium is precipitated by metallic zinc or by electrolysis.

Thallium bears a great resemblance to lead. It has a silver-like luster at a freshly-cut surface, but tarnishes rapidly in the air. It is malleable, but not ductile. Its specific gravity is 11.8; specific heat, .0325; melting point, 294° C.; atomic weight, 204. Nitric and sulphuric acids dissolve the metal readily, but hydrochloric acid has little action upon it. Surfaces of the metal exposed to the air become yellowish. The yellowish film readily dissolves off in water, and the surface regains its metallic appearance.

There are two series of compounds, the thallous, in which thallium is monovalent, and the thallic, in which the metal is trivalent. Thallous oxide ($Tl_2O$) is a black compound, formed by heating the hydroxide (TlOH) to 100° C. in such a manner as to avoid further oxidation. The hydroxide is formed by exposing the metal to the action of air and water or by adding baryta water (barium hydroxide solution) to a solution of the sulphate. $Tl_2SO_4 + Ba(OH)_2 = BaSO_4 + 2TlOH$. Barium sulphate is a white precipitate, and thallous hydroxide remains in solution. From a concentrated solution crystals having the composition $TlOH, 2H_2O$ are deposited.

Thallic oxide ($Tl_2O_3$) may be prepared by burning the metal in oxygen. By adding a solution of sodium hypochlorite to thallous chloride, a brown precipitate is formed, having the formula $Tl(OH)_3$ (thallic hydroxide). By electrolysis of a solution of thallous oxide, black thallic oxide is deposited on the anode, probably in the form of a hydrate. Having now described the occurrence, properties and compounds of thallium, we will describe the thallium cell more in detail.

A cell was constructed as follows: A small glass vessel was partly filled with a dilute solution of thallous oxide, to which about 10 per cent. of potassium hydroxide was added to increase the conductivity. Electrodes of thin sheet iron, about 1 inch square, were covered with the electrolyte, and the cell was closed with a cork stopper. Upon sending a current of about one-quarter ampère through the electrolyte, spongy thallium separated on the cathode and thallic oxide on the anode. The thallic oxide deposited in a hard black coating, which had a tendency to scale off in places as the layer increased in thickness. There was no gasing, even when the current density was considerably increased. When the charging current was stopped and the cell short-circuited through a galvanometer, comparatively large currents could be obtained. No instrument was at hand for accurate measurement of the electromotive forces. However, indications were that it was little more than .5 volt.

The theoretical storage capacity of thallium and its oxides is very low, the value for thallic oxide being about 53.2 ampère hours per pound, and that for metallic thallium, used as the negative, about 59.5 ampère hours per pound. The corresponding figures for lead peroxide and metallic lead being respectively 101.6 and 117.3 ampère hours per pound, those for silver peroxide (AgO), positive and metallic iron negative, are respectively 195.7 and 433.3 ampère hours. While the theoreti-

cal capacity of thallium and its compounds is extremely low, yet it is much higher than has been obtained in practice by the use of any metal.

Comparing the thallium cell with the lead type, we find the following points of difference:

1. In the lead cell the active materials, both positive and negative, are insoluble* throughout the cycle of changes. In the thallium cell the active materials at both poles are insoluble during the charged state, and both soluble in the electrolyte when discharged.

2. The active material of the lead cell being insoluble when discharged, the charged or peroxidized particles are soon surrounded by the products of discharge, and a large proportion of the peroxide mass is prevented from taking part in the discharge, so a large proportion of the plate is inactive or is dead weight. In the thallium cell, as fast as the peroxide is reduced by discharge, the resulting compound goes into solution, and so leaves the remaining material fully exposed to further action.

3. With lead electrodes, the active material is securely fixed in a suitable grid once for all, while with the thallium cell unattacked sheets of metal suspended in the electrolyte receive a deposit at each charge and lose it at every discharge.

4. With the lead cell, the electrodes must undergo a forming process before they are ready for service, while with the thallium cell no such process is necessary.

5. In lead cells gasing occurs more or less throughout charge, and becomes violent towards the end. No gasing occurs in the thallium cell, unless it is at the end of charge, when the action has been carried too far and the electrolyte has been exhausted of thallous oxide.

6. In the lead cell, the active materials not being deposited from the solution, there is not introduced the difficulty of obtaining compact, evenly distributed and adherent deposits, that gives so much trouble in the thallium cell and in all others having soluble products.

7. The lead cell gives a high electromotive force while the thallium cell gives a low one.

8. The voltage must not fall below 1.6 in the lead cell, while in a cell of the thallium type a discharge to 0 voltage ought to do no harm.

9. The theoretical storage capacity of lead is nearly twice as high as that of thallium.

10. The cost of construction is more for the lead cell than for the thallium cell, owing to the preparation and formation of the plates in the former case.

11. The first cost of materials is low in the case of the lead cell, while it is comparatively high for thallium.

The thallium cell makes use of a metal generally considered to be rare. While it most frequently occurs in small quantities, it is quite widespread, being found in many pyritic zinc ores. The price of this metal is about $6 per pound. To show the possibilities of some of the rare metals for storage battery purposes, as far as cost is concerned, I quote from the "Mineral Industry," Vol. VIII, a statement by Mr Victor Lenher:

"It should be remembered that while a use has been found for many of the rare and high-priced elements, there are many more that owe their present market price only to the fact that the demand is limited to specimens for museums or to the small amounts that are needed for research work. For example, in 1895 thorium nitrate sold at $200 a pound, while to-day it can be bought in Germany for $3.33 per pound.

Even a reduction in price to a few dollars per pound might seem at first thought to be a prohibitively high price for a metal to be used in storage batteries, when lead and its oxides can be bought for a few cents a pound. However, this is not necessarily so, if the metal possesses properties specially adapted to storage work. For instance, a battery using a material which insures a long life with hard usage, can be easily utilized again without excessive waste, requires no tedious forming process for its preparation, gives a high capacity, a high electromotive force and a high efficiency, and is capable of retaining a charge for a reasonable length of time, would admit of using a metal whose cost is many times greater than the cost of lead.

High capacity is a very important factor, since the higher the capacity the smaller the amount of material required.

No metal has yet been found that meets all these requirements, or even the greater part of them. Thallium is lacking in many important points, but at the same time possesses some good features. In the first place, a great objection is the fact that it is a difficult matter to obtain good, evenly distributed, coherent and adherent deposits of metal or of peroxide. The peroxide is particularly troublesome, on account of its peeling off the electrode. Otherwise this type of cell would have a decided advantage, in that a fresh surface of active material is always exposed as the discharge proceeds, a large proportion of the material may be utilized and the discharge may be allowed to proceed to 0 voltage. The fact that in the thallium cell the active materials of both electrodes are formed from the electrolyte, and when discharged return to their original condition as electrolyte, ought to be a strong point in favor of long life, for, the electrodes being permanent, the difficulty would be temporary, and could be corrected by properly charging. Each charge is practically the same as putting in new electrodes in the lead cell.

Since the thallium is in solution as the oxide in one part of the cycle makes it easy to utilize the material from worn-out cells. Thallium compounds are easily manipulated chemically.

The fact that the discharge product is soluble in the electrolyte obviates the use of a special forming process. In the matter of capacity, thallium stands very low in the scale; low also in regard to the electromotive force it is capable of producing. Efficiency is a matter not yet determined, but it would probably be low, for the reason that it is difficult to obtain good deposits on the electrodes. There would probably be no difficulty in the retention of charge.

It is obvious that thallium is not a metal from which a practical battery could be developed, not so much on account of its high cost as on account of its non-adaptability to the purpose. Yet the thallium cell should be interesting from a scientific standpoint, from the fact that its higher oxide represents a new type of positive electrode material.

## ANNUAL MEETING AMERICAN ELECTROCHEMICAL SOCIETY.

At the meeting of the Board of Directors of the American Electrochemical Society, held on November 6th, it was decided that the next general meeting will be held in New York City, on Thursday, Friday and Saturday of the week following Easter Sunday, i. e., April 16, 17 and 18, 1903. On Thursday, April 16th, the annual business meeting will be held, at 10.30 A. M., when the results of the election of officers will be announced. The program for the other days has not yet been arranged.

The suggestion to hold in autumn a meeting in Sault Ste Marie, simultaneously with the meeting of the American Institute of Electrical Engineers, was favorably looked upon, but no definite decision has yet been reached.

There appears to be a difficulty in arranging this simultaneous meeting, because the American Institute of Electrical Engineers have usually held their annual summer meeting in the early summer, generally in June. On the other hand, it would be impossible for the American Electrochemical Society to hold again a general meeting in June, so shortly after the annual business meeting, which must be held in March or April, according to the constitution.

* Here, all metals are considered to be insoluble in water or acids. In a strict sense, metals are not soluble in water or acids, but products may result which are soluble in these media.

## PIONEERS OF ELECTROCHEMISTRY—III.

### Edward Goodrich Acheson.

Edward Goodrich Acheson was born in Washington, Pa., March 9, 1856. His education was received at the Bellefonte Academy, Bellefonte, Pa., he finding it necessary to leave in 1872, before completing his course. Immediately after leaving school he joined a civil engineer corps on railroad construction as chainman, and followed this line of work for several years, eventually rising to the position of transit-man.

Acheson had always exhibited an intense interest in scientific subjects, and followed with great interest the newspaper descriptions of Edison's work at Menlo Park, being finally so captivated with electrical studies that he determined to seek a position in that line of scientific work. He was at that time living in the Pennsylvania oil fields at Bradford, in the employ of the Standard Oil Co. He resigned this position, and some little time later arrived in New York City and made application to Mr. Weston, at Newark, N. J., for a position. Failing there, he applied to the Western Electric Co., New York, and in turn several other of the early electrical establishments of that day, finally going to Menlo Park, where he was fortunate in securing employment in Mr. Edison's laboratory in the capacity of draftsman. Mr. Edison seems to have quickly appreciated his worth, and promotion following, he was within two months in charge of original experimental work in the laboratory.

E. G. Acheson

Acting on Mr. Edison's advice, Acheson gave particular attention to the manufacture of the new incandescent lamp, and on July 20, 1881, he was sent to Europe as assistant engineer of the Edison interests abroad. His first duties in the new field were more or less of an official character in the electrical exhibition at Paris, 1881. At the close of the Exposition he was given charge of, and constructed, the installation of the lamp factory in Edison's plant at Ivry-sur-Seine. He later was sent out on a trip through Europe, installing lighting plants at Milan, Pisa, Brussels, Bergamo, Geneo, Antwerp and many other places. Several Edison companies were formed as the result of this tour. Acheson left the Edison interests about the beginning of 1883, and took up private experimental work on electric batteries and thermopiles, the results of which were not satisfactory.

Returning to the United States in January, 1884, Acheson renewed his connection with the Edison interests, but shortly afterwards he again became engaged in private experimental work, which having been carried on for some few months, he accepted the position of superintendent of the Consolidated Lamp Co. of Brooklyn, with whom he remained but a few months, once more returning to his private experimental work on the conversion of heat energy into electrical energy. In 1886, he was appointed electrician of the Standard Underground Cable Co., of Pittsburg, and after filling this position for three years, he resigned and once more returned to private experimental field. In order to have greater facilities with which to carry on his experiments, Acheson organized a local electric-light plant at Monongahela, Pa., which began operations November 20, 1890. With the large power and many facilities at hand, a great variety of experiments were undertaken, one made in March of 1901 resulting in the production of that now well-known material "carborundum." Acheson had made an experiment in Edison's laboratory in the winter of 1880, which was productive of a substance of remarkable hardness, and at that time it occurred to him that it might be of value as an abrasive material. After a lapse of more than ten years, he made the experiment of mixing clay and carbon together, placed it in an iron bowl which was connected with one terminal of his dynamo, and, embedded in the mixture, he placed an arc light carbon, which was connected with the other terminal of the dynamo. A sufficient current to raise the mixture to a high temperature having been passed for some time, Acheson observed a few bright blue and black crystals attached to and surrounding the carbon rod. These crystals he named carborundum, and immediately began its manufacture in a small way. His production for the following six months amounted to about ¼ pound per day, and the material was sold to the lapidaries and machinists for grinding purposes.

The preliminary experiments in the manufacture proving encouraging, a stock company was organized in the fall of the same year, under the title "The Carborundum Co.," and they began operations at Monongahela City. In 1894, the large power development of Niagara Falls approaching completion, Acheson decided to establish a large plant at that place, but his stockholders were unwilling to subscribe to such movement, and Acheson, having disposed of a number of his patents in Enrope, used his own means for the construction of a large modern plant at Niagara Falls. After this plant was in operation, carborundum was produced in large quantities and was correspondingly cheaper in price, but still so much more expensive than emery that the emery-wheel makers refused to buy the material, and it was forced upon the company to enter into the manufacture of carborundum goods. The three years following were devoted to perfecting the manufacture, not only of carborundum, but of the articles made from it, and the material made rapid advancement in its applications to the various arts, in many instances entirely supplanting the emery goods. During this period there was added to the plant a department for the manufacture of carborundum paper and cloth, this proving equally as successful as the other lines of manufacture. It is interesting to note that the first sale of carborundum in 1891 was 200 carats, at 30 cents per carat, or $560 per pound, while in 1901 the output was 3,838,000 pounds, sold at an average price of 10 cents per pound.

Finally, in 1897, the carborundum problems having been com-

pletely solved and the opening of a market well started, Acheson turned his attention to the manufacture of graphite from amorphous carbon. In the manufacture of carborundum, some of that material was occasionally decompsed, owing to excessively high temperatures, and he noticed that a fine flake graphite was left as a result of the decomposition. Carborundum, or—to use its chemical name—silicon carbide, containing equal atomic proportions of the two elements of which it was composed, Acheson recognized that by heat they could be separated, the silicon volatilizing and the carbon secured as graphite. He took out patents protecting this method of manufacturing graphite, and after some further experimenting entered upon its commercial manufacture. A stock company was formed, called the Acheson Graphite Co., which was later absorbed by a new organization, the International Acheson Graphite Co. In 1891 this company produced about 2,500,000 pounds of graphite, of which 1,100,000 pounds were in the form of graphite electrodes. These electrodes have proved of great assistance in the development of electrochemical industries, as graphite in this form has been found to give excellent results.

Too much credit cannot be given the man who with so much self-sacrifice and perseverance built up these two industries to their present substantial footings. Although he met with many failures and disappointments, he was at no time discouraged and always took up the work with renewed determination.

Mr. Acheson has received several medals for his work, among which may be mentioned the following: Two medals from the Franklin Institute—one being for carborundum and the other for graphite; a gold medal from the World's Columbian Exposition, for carborundum; a gold medal from the Trans-Continental Exposition at Omaha, for carborundum and graphite; a gold medal from the Pan-American Exposition, at Buffalo, for the same; and a grand prix at Paris Exposition, 1900, for an exhibit of carborundum and graphite.

Mr. Acheson is a member of the American Institute of Electrical Engineers; American Association for the Advancement of Science, and a manager of the American Electrochemical Society.

## LOW TEMPERATURE RESEARCHES.*

By JAMES DEWAR,

*President of the British Association for the Advancement of Science*

### HISTORY OF THE RESEARCHES ON THE ABSOLUTE ZERO POINT OF TEMPERATURE.

THE nature of heat and cold must have engaged thinking men from the very earliest dawn of speculation upon the external world, but it will suffice for the present purpose if, disregarding ancient philosophers, and even mediæval alchemists, we take up the subject where it stood after the great revival of learning, and as it was regarded by the father of the inductive method. That this was an especially attractive subject to Bacon is evident from the frequency with which he recurs to it in his different works, always with lamentation over the inadequacy of the means at disposal for obtaining a considerable degree of cold. The great Robert Boyle was the first experimentalist who followed up Bacon's suggestion. In 1682 Boyle read a paper to the Royal Society on "New Experiments and Observations Touching Cold, or an Experimental History of Cold," published two years later in a separate work. This is really a most complete history of everything known about cold up to that date, but its great merit is the inclusion of numerous experiments made by Boyle himself on frigorific mixtures and the general effects of such upon matter. The agency chiefly used by Boyle in the conduct of his experiments was the glaciating mixture of snow or ice and salt. In the course of his experiment he made many important observations. Thus he observed that the salts which did not help the snow or ice to dissolve faster gave no effective freezing. He showed that water in becoming ice expands by about one-ninth of its volume and bursts gun barrels. He attempted to counteract the expansion and prevent freezing by completely filling a strong iron ball with water before cooling, anticipating that it might burst the bottle by the stupendous forces of expansion, or that if it did not, then the ice produced might, under the circumstances, be heavier than water. He speculated in an ingenious way on the change of water into ice Thus he says: "If cold be but a privation of heat through the recess of that ethereal substance which agitated the little eel-like particles of the water, and thereby made them compose a fluid body, it may easily be conceived that they should remain rigid in the postures in which the ethereal substances quitted them, and thereby compose an unfluid body like ice. Yet how these little eels should by that recess acquire as strong an endeavor outwards, as if they were so many little springs, and expand themselves with so stupendous a force, is that which does not so readily appear." The greatest degree of adventitious cold Boyle was able to produce did not make air exposed to its action lose a full tenth of its own volume, so that, in his own words, the cold does not "weaken the spring by anything near so considerable as one would expect." After making this remarkable observation and commenting upon its unexpected nature, it is strange Boyle did not follow it up He questions the existence of a body of its own nature supremely cold, by participating in which all other bodies obtain that quality, although the doctrine of a *primum frigidum* had been accepted by many sects of philosophers. The whole elaborate investigation cost Boyle immense labor, and he confesses that he "never handled any part of natural philosophy that was so troublesome and full of hardships." He looked upon his results but as a "beginning" in this field of inquiry. After the masterly essay of Boyle, the attention of investigators was chiefly directed to improving thermometrical instruments. The old air thermometer of Galileo being inconvenient to use, the introduction of fluid thermometers greatly aided the inquiry into the action of heat and cold. For a time great difficulty was encountered in selecting proper fixed points on the scales of such instruments, and this stimulated men like Huygens, Newton, Hooke and Amontons to suggest remedies and to conduct experiments. By the beginning of the eighteenth century the freezing point and the boiling point of water were agreed upon as fixed points, and the only apparent difficulties to be overcome were the selection of the fluid, accurate calibration of the capillary tube of the thermometer and a general understanding as to scale divisions. It must be confessed that great confusion and inaccuracy in temperature observations arose from the variety and crudeness of the instruments. This led Amontons, in 1702-1703, to contribute two papers to the French Academy which reveal great originality in the handling of the subject, and which, strange to say, are not generally known The first discourse deals with some new properties of the air and the means of accurately ascertaining the temperature in any climate. He regarded heat as due to a movement of the particles of bodies, though he did not in any way specify the nature of the motion involved; and as the general cause of all terrestrial motion, so that in its absence the earth would be without movement in its smallest parts. The new facts he records are observations on the pressure of air brought about by the action of heat. He shows that the ratio of the total pressure of air at two definite and steady temperatures and at constant volume is a constant, independent of the mass or the initial pressure of the air in thermometer. These results led to the increased perfection of the air thermometer as a standard instrument, Amontons' idea being to express the tempera-

* Presidential Address, delivered at the recent Belfast meeting of the British Association for the Advancement of Science (Lack of space requires the omission of the introductory remarks of the address; the historical notes in the chapter on the "History of the Researches on the Absolute Zero Point of Temperature" have also been slightly abridged. —Ed.)

ture of any locality in fractions of the degree of heat of boiling water. The great novelty of the instrument is that temperature is defined by the measurement of the length of a column of mercury. In passing, he remarks that we do not know the extreme of heat and cold. In the following year Amontons contributed to the Academy a further paper extending the scope of the inquiry. He there pointed out more explicitly that as the degrees of heat in his thermometer are registered by the height of a column of mercury, which the heat is able to sustain by the pressure or "spring" of the air, it follows that the extreme cold of the thermometer will be that which reduces the air to have no power of spring. This, he says, will be a much greater cold than what we call "very cold," because experiments have shown that if the "spring" of the air at boiling point is 73 inches, the degree of heat which remains in the air when brought to the freezing point of water is still very great, for it can still maintain the spring of 51½ inches. The greatest climatic cold on the scale of units adopted by Amontons is marked 50, and the greatest summer heat is 58, the value for boiling water being 73 and the zero being 52 units below the freezing point. Thus Amontons was the first to recognize that the use of air as a thermometric substance led to the inference of the existence of a zero of temperature, and his scale is nothing else than the absolute one we are now so familiar with. If we adopt the Celsius scale of temperature, then the zero of Amontons' air thermometer is *minus* 240 degrees. This is a remarkable approximation to our modern value for the same point of *minus* 273 degrees. It has to be confessed that Amontons' valuable contributions to knowledge met with that fate which has so often for a time overtaken the work of too-advanced discoverers. In other words, it was simply ignored, or, in any case, not appreciated by the scientific world, either of that time or half a century later. It is not till Lambert, in his work on "Pyrometrie," published in 1779, repeated Amontons' experiments and indorsed his results that we find any further reference to the absolute scale or the zero of temperature. Lambert's observations were made with the greatest care and refinement, and resulted in correcting the value of the zero of the air scale to *minus* 270 degrees, as compared with Amontons' *minus* 240 degrees. Lambert points out that the degree of temperature which is equal to zero is what one may call absolute cold, and that at this temperature the volume of the air would be practically nothing. In other words, the particles of the air would fall together and touch each other and become dense like water; and from this it may be inferred that the gaseous condition is caused by heat. Lambert says that Amontons' discoveries had found few adherents, because they were too beautiful and advanced for the time in which he lived.

About this time a remarkable observation was made by Professor Braun at Moscow, who, during the severe winter of 1759, succeeded in freezing mercury by the use of a mixture of snow and nitric acid. When we remember that mercury was regarded as quite a peculiar substance, possessed of the essential quality of fluidity, we can easily understand the universal interest created by the experiment of Braun. This was accentuated by the observations he made on the temperature given by the mercury thermometer, which appeared to record a temperature as low as *minus* 200° C. The experiments were soon repeated by Hutchins at Hudson's Bay, who conducted his work with the aid of suggestions given him by Cavendish and Black. The result of the new observations was to show that the freezing point of mercury is only *minus* 40° C., the errors in former experiments having been due to the great contraction of the mercury in the thermometer in passing into the solid state. From this it followed that the enormous natural and artificial colds which had generally been believed in had no proved existence. Still the possible existence of a zero of temperature very different from that deduced from gas thermometry had the support of such distinguished names as those of Laplace and Lavoisier. In their great memoir on "Heat," after making what they consider reasonable hypotheses as to the relation between specific heat and total heat, they calculate values for the zero, which range from 1,500° to 3,000° below melting ice. On the whole, they regard the absolute zero as being in any case 600° below the freezing point. Lavoisier, in his "Elements of Chemistry," published in 1792, goes further in the direction of indefinitely lowering the zero of temperature. Even as late as the beginning of the nineteenth century we find Dalton, in his new system of "Chemical Philosophy," adopting finally as the natural zero of temperature *minus* 3,000° C.

In Black's lectures we find that he takes a very cautious view with regard to the zero of temperature, but, as usual, is admirably clear with regard to its exposition. Thus he says: "We are ignorant of the lowest possible degree or beginning of heat. Some ingenious attempts have been made to estimate what it may be, but they have not proved satisfactory. Our knowledge of the degrees of heat may be compared to what we should have of a chain, the two ends of which were hidden from us and the middle only exposed to our view. We might put distinct marks on some of the links, and number the rest according as they are nearest to or further removed from the principal links. But, not knowing the distance of any links from the end of the chain, we could not compare them together with respect to their distance or say that one link was twice as far from the end of the chain as another." It is interesting to observe, however, that Black was evidently well acquainted with the work of Amontons, and strongly supports his inference as to the nature of air. Black's own special contribution to low-temperature studies was his explanation of the interaction of mixtures of ice with salts and acids by applying the doctrine of the latent heat of fluidity of ice to account for the frigorific effect. In a similar way Black explained the origin of the cold produced in Cullen's remarkable experiment of the evaporation of ether under the receiver of an air pump by pointing out that the latent heat of vaporization in this case necessitated such a result. Thus, by applying his own discoveries of latent heat, Black gave an intelligent explanation of the cause of all the low-temperature phenomena known in his day.

After the gaseous laws had been definitely formulated by Gay-Lussac and Dalton, the question of the absolute zero of temperature, as deduced from the properties of gases, was revived by Clement and Desormes. These distinguished investigators presented a paper on the subject to the French Academy in 1812, which, it appears, was rejected by that body. The authors subsequently elected to publish it in 1819. Relying on what we know now to have been a faulty hypothesis, they deduced from observations on the heating of air rushing into a vacuum the temperature of *minus* 267 degrees as that of the absolute zero. They further endeavored to show, by extending to lower temperatures the volume or the pressure coefficients of gases given by Gay-Lussac, that at the same temperature of *minus* 267 degrees the gases would contract so as to possess no appreciable volume, or, alternately, if the pressure was under consideration, it would become so small as to be non-existent. Although full reference is given to previous work bearing on the same subject, yet, curiously enough, no mention is made of the name of Amontons. It certainly gave remarkable support to Amontons' notion of the zero to find that simple gases like hydrogen and compound gases like ammonia, hydrochloric, carbonic and sulphurous acids should all point to substantially the same value for this temperature. But the most curious fact about this research of Clement and Desormes is that Gay-Lussac was a bitter opponent of the validity of the inferences they drew either from his work or their own. The mode in which Gay-Lussac regarded the subject may be succinctly put as follows: A quick compression of air to one-fifth volume raises its temperature to 300 degrees, and if this could be made much greater and instantaneous the temperature might rise to 1,000 or 2,000 degrees. Conversely,

if air under five atmospheres were suddenly dilated, it would absorb as much heat as it had evolved during compression, and its temperature would be lowered by 300 degrees. Therefore, if air were taken and compressed to 50 atmospheres or more, the cold produced by its sudden expansion would have no limit. In order to meet this position, Clement and Desormes adopted the following reasoning: They pointed out that it had not been proved that Gay-Lussac was correct in his hypothesis, but that in any case it tacitly involves the assumption that a limited quantity of matter possesses an unlimited supply of heat. If this were the case, then heat would beb unlike any other measurable thing or quality. We know now that Gay-Lussac was wrong in supposing the increment of temperature arising from a given gaseous compression would produce a corresponding decrement from an identical expansion. After this time the zero of temperature was generally recognized as a fixed ideal point, but, in order to show that it was hypothetical, a distinction was drawn between the use of the expressions, zero of absolute temperature and the absolute zero.

The whole question took an entirely new form when Lord Kelvin, in 1848, after the mechanical equivalent of heat had been determined by Joule, drew attention to the great principles underlying Carnot's work on the "Motive Power of Heat," and applied them to an absolute method of temperature measurement, which is completely independent of the properties of any particular substance. The principle was that for a difference of one degree on this scale, between the temperatures of the source and refrigerator, a perfect engine should give the same amount of work in every part of the scale. Taking the same fixed points as for the Centigrade scale, and making 100 of the new degrees cover that range, it was found that the degrees not only within that range, but as far beyond as experimental data supplied the means of comparison, differed by only minute quantities from those of Regnault's air thermometer. The zero of the new scale had to be determined by the consideration that when the refrigerator was at the zero of temperature the perfect engine should give an amount of work equal to the full mechanical equivalent of the heat taken up. This led to a zero of 273 degrees below the temperature of freezing water, substantially the same as that deduced from a study of the gaseous state. It was a great advance to demonstrate by the application of the laws of thermodynamics not only that the zero of temperature is a reality, but that it must be located at 273 degrees below the freezing point of water. As no one has attempted to impugn the solid foundation of theory and experiment on which Lord Kelvin based his thermodynamic scale, the existence of a definite zero of temperaturre must be acknowledged as a fundamental scientific fact.

### LIQUEFACTION OF GASES AND CONTINUITY OF STATE.

In these speculations, however, chemists were dealing theoretically with temperatures to which they could not make any but the most distant experimental approach. Cullen, the teacher of Black, had indeed shown how to lower temperature by the evaporation of volatile bodies, such as ether, by the aid of the air pump; and the later experiments of Leslie and Wollaston extended the same principle. Davy and Faraday made the most of the means at command in liquefying the more condensable gases, while at the same time Davy pointed out that they in turn might be utilized to procure greater cold by their rapid reconversion into the aeriform state. Still, the chemist was sorely hampered by the want of some powerful and accessible agent for the production of temperatures much lower than had ever been attained. That want was supplied by Thilorier, who in 1835 produced liquid carbonic acid in large quantities, and further made the fortunate discovery that the liquid could be frozen into a snow by its own evaporation. Faraday was prompt to take advantage of this new and potent agent. Under exhaustion he lowered its boiling point from *minus* 78° C. to *minus* 110° C., and, by combining this low temperature with pressure, all the gases were liquefied by the year 1844, with the exception of the three elementary gases—hydrogen, nitrogen and oxygen—and three compound gases—carbonic oxide, marsh gas and nitric oxide. Andrews, some twenty-five years after the work of Faraday, attempted to induce change of state in the uncondensed gases by using much higher pressures than Faraday employed. Combining the temperature of a solid carbonic acid bath with pressures of 300 atmospheres, Andrews found that none of these gases exhibited any appearance of liquefaction in such high states of condensation. But, so far as change of volume by high compression went, Andrews confirmed the earlier work of Natterer by showing that the gases become proportionately less compressible with growing pressure. While such investigations were proceeding, Regnault and Magnus had completed their refined investigations on the laws of Boyle and Gay-Loussac. A very important series of experiments were made by Joule and Kelvin "On the Thermal Effects of Fluids in Motion," about 1862, in which the thermometrical effects of passing gases under compression through porous plugs furnished important data for the study of the mutual action of the gas molecules. No one, however, had attempted to make a complete study of a liquefiable gas throughout wide ranges of temperature. This was accomplished by Andrews in 1869, and his Bakerian lecture "On the Continuity of the Gaseous and Liquid States of Matter" will always be regarded as an epoch-making investigation. During the course of this research Andrews observed that liquid carbonic acid raised to a temperature of 31° C. lost the sharp concave surface of demarcation between the liquid and the gas, the space being now occupied by a homogeneous fluid, which exhibited, when the pressure was suddenly diminished or the temperature slightly lowered, a peculiar appearance of moving or flickering striæ, due to great local alterations of density. At temperatures above 31° C. the separation into two distinct kinds of matter could not be effected, even when the pressure reached 400 atmospheres. This limiting temperature of the change of state from gas to liquid Andrews called the critical temperature. He showed that this temperature is constant, and differs with each substance, and that it is always associated with a definite pressure peculiar to each body. Thus the two constants, critical temperature and pressure, which have been of the greatest importance in subsequent investigations, came to be defined, and a complete experimental proof was given that "the gaseous and liquid states are only distinct stages of the same condition of matter and are capable of passing into one another by a process of continuous change."

In 1873 an essay "On the Continuity of the Gaseous and Liquid State," full of new and suggestive ideas, was published by van der Waals, who, recognizing the value of Clausius' new conception of the virial in dynamics, for a long-continued series of motions, either oscillatory or changing exceedingly slow with time, applied it to the consideration of the molecular movements of the particles of the gaseous substance and, after much refined investigation and the fullest experimental calculation available at the time, devised his well-known equation of continuity. Its paramount merit is that it is based entirely on a mechanical foundation, and is in no sense empiric, we may therefore look upon it as having a secure foundation in fact, but also as being capable of extension and improvement. James Thomson, realizing that the straight-line breach of continuous curvature in the Andrews isothermals was untenable to the physical mind, propounded his emendation of the Andrews curves, namely, that they were continuous and of S form. We also owe to James Thomson the conception and execution of a three-dimensional model of Andrews' results, which has been of the greatest service in exhibiting the three variables by means of a specific surface, afterwards greatly extended and developed by Prof. Willard Gibbs. The suggestive work of James Thomson undoubtedly was a valuable aid to van der Waals, for, as soon as he reached the point where his equation had to show the continuity of the two states,

was the first difficulty he had to encounter, and he succeeded in giving the explanation. He also gave a satisfactory reason for the existence of a minimum value of the product of volume and pressure in the Regnault isothermals. His isothermals, with James Thomson's completion of them, were now shown to be the results of the laws of dynamics. Andrews applied the new equation to the consideration of the coefficients of expansion with temperature and of pressure with temperature, showing that although they were nearly equal, nevertheless they were almost independent quantities. His investigation of the capillarity constant was masterly, and he added further to our knowledge of the magnitudes of the molecules of gases and of their mean free paths. Following up the experiments of Joule and Kelvin, he showed how their cooling coefficients could be deduced, and proved that they vanished at a temperature in each case, which is a constant multiple of the specific critical temperature. The equation of continuity developed by van der Waals involved the use of three constants instead of one, as in the old law of Boyle and Charles, the latter being only utilized to express the relation of temperature, pressure and volume, when the gas is far removed from its point of liquefaction. Of the two new constants, one represents the molecular pressure arising from the attraction between the molecules, the other four times the volume of the molecules. Given these constants of a gas, van der Waals showed that his equation not only fitted into the general characters of the isothermals, but also gave the values of the critical temperature, the critical pressure and the critical volume. In the case of carbonic acid, the theoretical results were found to be in remarkable agreement with the experimental values of Andrews. This gave chemists the means of ascertaining the critical constants, provided sufficiently accurate data derived from the study of a few properly-distributed isothermals of the gaseous substance were available. Such important data came into the possession of chemists when Amagat published his valuable paper on "The Isothermals of Hydrogen, Nitrogen, Oxygen, Ethylene," etc., in the year 1880. It now became possible to calculate the critical data with comparative accuracy for the so-called permanent gases oxygen and nitrogen, and this was done by Sarrau in 1882. In the meantime a great impulse had been given to a further attack upon the so-called permanent gases by the suggestive experiments made by Pictet and Cailletet. The static liquefaction of oxygen was effected by Wroblewski in 1883, and thereby the theoretical conclusions derived from van der Waals' equation were substantially confirmed. The liquefaction of oxygen and air was achieved through the use of liquid ethylene as a cooling agent, which enabled a temperature of *minus* 140 degrees to be maintained by its steady evaporation *in vacuo*. From this time liquid oxygen and air came to be regarded as the potential cooling agents for future research, commanding as they did a temperature of 200 degrees below melting ice. The theoretical side of the question received at the hands of van der Waals a second contribution, which was even more important than his original essay, and that was his novel and ingenious development of what he calls "The Theory of Corresponding States." He defined the corresponding states of two substances as those in which the ratios of the temperature, pressure and volume to the critical temperature, pressure and volume respectively were the same for the two substances, and in corresponding states he showed that the three pairs of ratios all coincided. From this a series of remarkable propositions were developed, some new, some proving previous laws that were hitherto only empiric and some completing and correcting faulty, though approximate, laws. As examples, he succeeded in calculating the boiling point of carbonic acid from observations on ether vapor, proved Kopp's law of molecular volumes and showed that at corresponding temperatures the molecular latent heats of vaporization are proportional to the absolute critical temperature, and that under the same conditions the coefficients of liquid expansion are inversely proportional to the absolute critical temperature and that the coefficients of liquid compressibility are inversely proportional to the critical pressure. All these propositions and deductions are in the main correct, though further experimental investigation has shown minor discrepancies requiring explanation. Various proposals have been made to supplement van der Waals' equation so as to bring it into line with experiments, some being entirely empiric, others theoretical. Clausius, Sarrau, Wroblewski, Batteli and others attacked the question empirically, and in the main preserved the co-volume (depending on the total volume of the molecules) unaltered while trying to modify the constant of molecular attraction. Their success depended entirely on the fact that, instead of limiting the number of constants to three, some of them have increased them to as many as ten. On the other hand, a series of very remarkable theoretical investigations have been made by van der Waals himself, by Kammerlingh Onnes, Korteweg, Jaeger, Boltzmann, Dieterici and Rienganum and others, all directed in the main towards an admitted variation in the value of the co-volume, while preserving the molecular attraction constant. The theoretical deductions of Tait lead to the conclusion that a substance below its critical point ought to have two different equations of the van der Waals type, one referring to the liquid and the other to the gaseous phase. One important fact was soon elicited, namely, that the law of correspondence demanded only that the equation should contain not more than three constants for each body. The simplest extension is that made by Reinganum, in which he increased the pressure for a given mean kinetic energy of the particles inversely in the ratio of the diminution of free volume, due to the molecules possessing linear extension. Berthelot has shown how a "reduced" isothermal may be got by taking two other prominent points as units of measurement instead of the critical co-ordinates. The most suggestive advance in the improvement of the van der Waals equation has been made by a lady, Mme. Christine Meyer. The idea at the base of this new development may be understood from the following general statement: van der Waals brings the van der Waals surfaces for all substances into coincidence at the point where volume, pressure and temperature are nothing, and then stretches or compresses all the surfaces parallel to the three axes of volume, pressure and temperature until their critical points coincide. But on this plan the surfaces do not quite coincide, because the points where the three variables are respectively nothing are not corresponding points. Mme. Meyer's plan is to bring all the critical points first into coincidence, and then to compress or extend all the representative surfaces parallel to the three axes of volume, pressure and temperature until the surfaces coincide. In this way, taking 29 different substances, she completely verifies from experiment van der Waals' law of correspondence. The theory of van der Waals has been one of the greatest importance in directing experimental investigation and in attacking the difficult problems of the liquefaction of the most permanent gases. One of its greatest triumphs has been the proof that the critical constants and the boiling point of hydrogen theoretically deduced by Wroblewski from a study of the isothermals of the gas taken far above the temperature of liquefaction are remarkably near the experimental values. We may safely infer, therefore, that if hereafter a gas be discovered in small quantity, even four times more volatile than liquid hydrogen, yet by a study of its isothermals at low temperature we shall succeed in finding its most important liquid constants, although the isolation of the real liquid may for the time be impossible. It is perhaps not too much to say that as a prolific source of knowledge in the department dealing with the continuity of state in matter it would be necessary to go back to Carnot's cycle to find a proposition of greater importance than the theory of van der Waals and his development of the law of corresponding states.

It will be apparent from what has just been said that, thanks to the labors of Andrews, van der Waals and others, theory

had again far outrun experiment. We could calculate the constants and predict some of the simple physical characteristics of liquid oxygen, hydrogen or nitrogen with a high degree of confidence long before any one of the three had been obtained in the static liquid condition permitting of the experimental verification of the theory. This was the more tantalizing, because, with whatever confidence the chemist may anticipate the substantial corroboration of his theory, he also anticipates, with almost equal conviction, that as he approaches more and more nearly to the zero of absolute temperature he will encounter phenomena compelling modification, revision and refinement of formulas which fairly covered the facts previously known. Just as nearly seventy years ago chemists were waiting for some means of getting a temperature of 100 degrees below melting ice, so ten years ago they were casting about for the means of going 100 degrees lower still. The difficulty, it need hardly be said, increases in a geometrical rather than in an arithmetical ratio. Its magnitude may be estimated from the fact that to produce liquid air in the atmosphere of an ordinary laboratory is a feat analogous to the production of liquid water starting from steam at a white heat and working with all the implements and surroundings at the same high temperature. The problem was not so much how to produce intense cold, as how to save it when produced from being immediately leveled up by the relatively superheated surroundings. Ordinary non-conducting packings were inadmissible, because they are both cumbrous and opaque, while in working near the limits of our resources it is essential that the product should be visible and readily handled. It was while puzzling over this mechanical and manipulative difficulty in 1892 that it occurred to me that the principle of an arrangement used nearly twenty years before in some calorimetric experiments, which was based upon the work of Dulong and Petit on radiation, might be employed with advantage, as well as to protect cold substances from heat as hot ones from rapid cooling. I therefore tried the effect of keeping liquefied gases in vessels having a double wall, the annular space between being very highly exhausted. Experiments showed that liquid air evaporated at only one-fifth of the rate prevailing when it was placed in a similar unexhausted vessel, owing to the convective transference of heat by the gas particles being enormously reduced by the high vacuum. But, in addition, these vessels lend themselves to an arrangement by which radiant heat can also be cut off. It was found that when the inner walls were coated with a bright deposit of silver the influx of heat was diminished to one-sixth the amount entering without the metallic coating. The total effect of the high vacuum and the silvering is to reduce the ingoing heat to about 3 per cent. The efficiency of such vessels depends upon getting as high a vacuum as possible, and cold is one of the best means of effecting the desired exhaustion. All that is necessary is to fill completely the space that has to be exhausted with an easily-condensable vapor, and then to freeze it out in a receptacle attached to the primary vessel that can be sealed off. The advantage of this method is that no air pump is required, and that theoretically there is no limit to the degree of exhaustion that can be obtained. The action is rapid, provided liquid air is the cooling agent, and vapors like mercury, water or benzol are employed. It is obvious that when we have to deal with such an exceptionally volatile liquid as hydrogen the vapor filling may be omitted, because air itself is now an easily-condensable vapor. In other words, liquid hydrogen, collected in such vessels with the annular space full of air, immediately solidifies the air, and thereby surrounds itself with a high vacuum. In the same way, when it shall be possible to collect a liquid boiling on the absolute scale at about 5 degrees, as compared with the 20 degrees of hydrogen, then you might have the annular space filled with the latter gas to begin with, and yet get directly a very high vacuum, owing to the solidification of the hydrogen. Many combinations of vacuum vessels can be arranged, and the lower the temperature at which we have to operate the more useful they become. Vessels of this kind are now in general use, and in them liquid air has crossed the American continent. Of the various forms, that variety is of special importance which has a spiral tube joining the bottom part of the walls, so that any liquid gas may be drawn off from the interior of such a vessel. In the working of regenerative coils such a device becomes all-important, and such special vessels cannot be dispensed with for the liquefaction of hydrogen.

In the early experiments of Pictet and Cailletet cooling was produced by the sudden expansion of the highly-compressed gas, preferably at a low temperature, the former using a jet that lasted for some time, the latter an instantaneous adiabatic expansion in a strong glass tube. Neither process was practicable as a mode of producing liquid gases, but both gave valuable indications of partial change into the liquid state by the production of a temporary mist. Linde, however, saw that the continuous use of a jet of highly-compressed gas, combined with regenerative cooling, must lead to liquefaction on account of what is called the Kelvin-Joule effect: and he succeeded in making a machine, based on this principle, capable of producing liquid air for industrial purposes. These experiments had proved that, owing to molecular attraction, compressed gases passing through a porous plug or small aperture were lowered in temperature by an amount depending on the difference of pressure, and inversely as the square of the absolute temperature. This means that for a steady difference of pressure the cooling is greater the lower the temperature. The only gas that did not show cooling under such conditions was hydrogen. Instead of being cooled, it became actually hotter. The reason for this apparent anomaly in the Kelvin-Joule effect is that every gas has a thermometric point of inversion above which it is heated, and below which it is cooled. This inversion point, according to van der Waals, is six and three-quarter times the critical point. The efficiency of the Linde process depends on working with highly-compressed gas well below the inversion temperature, and in this respect this point may be said to take the place of the critical one, when in the ordinary way direct liquefaction is being effected by the use of specific liquid cooling agents. The success of both processes depends upon working with a certain temperature range, only the Linde method gives us a much wider range of temperature within which liquefaction can be effected. This is not the case if, instead of depending on getting cooling by the internal work done by the attraction of the gas molecules, we force the compressed gas to do external work, as in the well-known air machines of Kirk and Coleman. Both these inventors have pointed out that there is no limit of temperature, short of liquefaction of the gas in use in the circuit, that such machines are not capable of giving. While it is theoretically clear that such machines ought to be capable of maintaining the lowest temperatures, and that with the least expenditure of power, it is a very different matter to overcome the practical difficulties of working such machines under the conditions. Coleman kept a machine delivering air at *minus* 83 degrees for hours, but he did not carry his experiments any further. Recently Monsieur Claude, of Paris, has, however, succeeded in working a machine of this type so efficiently that he has managed to produce one liter of liquid air per horse-power expended per hour in the running of the engine. This output is twice as good as that given by the Linde machine, and there is no reason to doubt that the yield will be still further improved. It is clear, therefore, that in the immediate future the production of liquid air and hydrogen will be effected most economically by the use of machines producing cold by the expenditure of mechanical work.

### LIQUID HYDROGEN AND HELIUM.

To the physicist the copious production of liquid air by the methods described was of peculiar interest and value as affording the means of attacking the far more difficult problem of the liquefaction of hydrogen, and even as encouraging the hope that liquid hydrogen might in time be employed for the liquefaction of yet more volatile elements, apart from the importance

which its liquefaction must hold in the process of the steady advance towards the absolute zero. Hydrogen is an element of especial interest, because the study of its properties and chemical relations led great chemists like Faraday, Dumas, Daniell, Graham and Andrews to entertain the view that if it could ever be brought into the state of liquid or solid it would reveal metallic characters. Looking to the special chemical relations of the combined hydrogen in water, alkaline oxides, acids and salts, together with the behavior of these substances on electrolysis, we are forced to conclude that hydrogen behaves as the analogue of a metal. After the beautiful discovery of Graham that palladium can absorb some hundreds of times its own volume of hydrogen, and still retain its luster and general metallic character, the impression that hydrogen was probably a member of the metallic group became very general. The only chemist who adopted another view was my distinguished predecessor, Professor Odling. In his "Manual of Chemistry," published in 1861, he pointed out that hydrogen has chlorous as well as basic relations, and that they are as decided, important and frequent as its other relations. From such considerations he arrived at the conclusion that hydrogen is essentially a neutral or intermediate body, and therefore we should not expect to find liquid or solid hydrogen possess the appearance of a metal. This extraordinary prevision, so characteristic of Odling, was proved to be correct some thirty-seven years after it was made. Another curious anticipation was made by Dumas in a letter addressed to Pictet, in which he says that the metal most analogous to hydrogen is magnesium, and that probably both elements have the same atomic volume, so that the density of hydrogen, for this reason, would be about the value elicited by subsequent experiments. Later on, in 1872, when Newlands began to arrange the elements in periodic groups, he regarded hydrogen as the lowest member of the chlorine family; but Mendeleef, in his later classification, placed hydrogen in the group of the alkaline metals. On the other hand, Dr. Johnstone Stoney classes hydrogen with the alkaline earth metals and magnesium. From this speculative divergency it is clear no definite conclusion could be reached regarding the physical properties of liquid or solid hydrogen, and the only way to arrive at the truth was to prosecute low-temperature research until success attended the efforts to produce its liquefaction. This result I definitely obtained in 1898. The case of liquid hydrogen is, in fact, an excellent illustration of the truth already referred to, that no theoretical forecast, however apparently justified by analogy, can be finally accepted as true until confirmed by actual experiment. Liquid hydrogen is a colorless, transparent body of extraordinary intrinsic interest. It has a clearly-defined surface; is easily seen; drops well, in spite of the fact that its surface tension is only the thirty-fifth part of that of water, or about one-fifth that of liquid air, and can be poured easily from vessel to vessel. The liquid does not conduct electricity, and, if anything, is slightly diamagnetic. Compared with an equal volume of liquid air, it requires only one-fifth the quantity of heat for vaporization. On the other hand, its specific heat is ten times that of liquid air or five times that of water. The coefficient of expansion of the fluid is remarkable, being about ten times that of gas. It is by far the lightest liquid known to exist, its density being only one-fourteenth that of water. The lightest liquid previously known was liquid marsh gas, which is six times heavier. The only solid which has so small density as to float upon its surface is a piece of pith wood. It is by far the coldest liquid known. At ordinary atmospheric pressure it boils at *minus* 252.5 degrees or 20.5 degrees absolute. The critical point of the liquid is about 29 degrees absolute, and the critical pressure not more than 15 atmospheres. The vapor of the hydrogen arising from the liquid has nearly the density of air; that is, it is 14 times that of the gas at the ordinary temperature. Reduction of the pressure by an air pump brings down the temperature to *minus* 258 degrees, when the liquid becomes a solid resembling frozen foam; and this, by further exhaustion, is cooled to *minus* 260 degrees, or 13 degrees absolute, which is the lowest steady temperature that has been reached. The solid may also be got in the form of a clear, transparent ice, melting at about 15 degrees absolute, under a pressure of 55 mm., possessing the unique density of one-eleventh that of water. Such cold involves the solidification of every gaseous substance but one that is at present definitely known to the chemist, and so liquid hydrogen introduces the investigator to a world of solid bodies. The contrast between this refrigerating substance and liquid air is most remarkable. On the removal of the loose plug of cotton wool used to cover the mouth of the vacuum vessel in which it is stored, the action is followed by a miniature snow storm of solid air, formed by the freezing of the atmosphere at the point where it comes into contact with the cold vapor rising from the liquid. This solid air falls into the vessel and accumulates as a white snow at the bottom of the liquid hydrogen. When the outside of an ordinary test tube is cooled by immersion in the liquid, it is soon observed to fill up with solid air; and if the tube be now lifted out a double effect is visible, for liquid air is produced both in the inside and on the outside of the tube—in the one case by the melting of the solid, and in the other by condensation from the atmosphere. A tuft of cotton wool soaked in the liquid and then held near the pole of a strong magnet is attracted, and it might be inferred therefrom that liquid hydrogen is a magnetic body. This, however, is not the case; the attraction is due neither to the cotton-wool nor to the hydrogen—which, indeed, evaporates almost as soon as the tuft is taken out of the liquid—but to the oxygen of the air, which is well known to be a magnetic body, frozen in the wool by the extreme cold.

[*To be concluded.*]

## PROF. ROWLAND'S PAPERS.

"Science" states that the volume containing the physical papers of the late Prof. Henry A. Rowland is now nearly ready for distribution to its subscribers. It has been edited under the direction of a committee consisting of President Remsen, Professor Welch and Professor Ames. In the book, which contains about 750 pages, are collected not alone Professor Rowland's strictly scientific papers and his public addresses, but also a detailed description of his ruling engine, with plates and photographs. The memorial address of Professor Mendenhall serves as a biographical sketch, which is accompanied by a portrait of Professor Rowland. The subjects treated in these papers cover a wide range. In heat there is the great memoir on the mechanical equivalent of heat, with several shorter articles on thermometers. In electricity and magnetism there are the fundamental researches on magnetization, on the magnetic effort of electrical connection, on the value of the ohm, on the theory and use of alternating currents, etc. In light there are the renowned discovery and theory of the concave grating and the long series of investigations made in the field of spectroscopy.

## OBITUARY.

John Hall Gladstone, D.Sc., Ph.D., F.R.S., died, on October 6th, in London. His name is best known in electrochemical circles, from the fact that some fifteen years ago he worked out, in conjunction with Dr. Tribe, the so-called double sulphate theory of the lead storage battery. This theory has since been repeatedly tested, and is now generally accepted, especially since Dolezalek's elaborate recent researches. Dr. Gladstone reached an age of seventy-five years.

The Institution of Electrical Engineers of Great Britain has accepted the invitation of the American Institute of Electrical Engineers to hold a joint meeting in 1904 in the United States.

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

BY GEORGE P. SCHOLL.

ELECTRIC FURNACES AND FURNACE PRODUCTS.

*Process of Manufacturing Calcium Carbide.* Isaiah L. Roberts, New York. Patent No. 708,921, September 9, 1902. Application filed March 18, 1897.

The process consists essentially in the substitution of finely-ground anthracite coal for coke in the mixture of raw materials for the carbide furnace. Coke, as a component of the mixture, is said to be objectionable for various reasons—principally because, on account of its low specific gravity, it tends to float on top of the melted carbide, and is therefore only partially converted into carbide. As a consequence, a kind of segregation manifests itself in the block of carbide produced, which will show itself in the variations of chemical composition. A further disadvantage is stated to be that finely-ground coke gives rise to clouds of dust, and on that account is extremely objectionable to the workmen. Anthracite coal is of a higher specific gravity than coke, and, moreover, it does not have that dust-forming tendency of coke. The carbide thus produced is said not to burn so readily upon its surface when it is removed from the furnace as the product obtained from coke, and an increased yield is also claimed. The proportion may be the same as ordinarily employed, but a somewhat less proportion of anthracite also works satisfactorily. As far as anthracite coal is concerned as a raw material in the manufacture of calcium carbide, it does not seem to be used in this country. In the practice of the Union Carbide Co., Niagara Falls, N. Y. (Richards, "Electrochemical Industries," 1902, p. 22), ground coke is used in connection with burnt lime, and this company control almost all the carbide production in America. In Europe, however, and especially in France, anthracite is already used in the manufacture of calcium carbide, as appears from a paper read by Gall, on the "Industry of Calcium Carbide in France," before the Fourth International Congress of Applied Chemistry, at Paris, 1900. He says: "Charcoal, coke and anthracite have been used industrially. . . . The manufacturers of calcium carbide have preferred to avail themselves of the anthracite, which England continues to furnish of excellent quality. The anthracites of the Alps are, unfortunately, too impure. It is, however, interesting to note the ingenious solution of the problem found by the Compagnie de Fives-Lille. The anthracites of Bosel (Tarentaire), where the works are situated, leave an ash consisting almost entirely of silica, and a method is used by the company which permits them to obtain a product of the highest interest for metallurgy, together with the carbide, namely, ferro silicon, remarkable specimens of which were exhibited at the exposition." As the application for the patent was made in March, 1897, it has taken more than five years to get it through the Patent Office. An industry like that of calcium carbide, which has made such rapid strides in the course of comparatively few years, could hardly be expected to wait that long for the suggestion of improvements.

*Carborundum Articles, and Process of Making Same.* Frank J. Tone, Niagara Falls, N. Y. Patent No. 709,808, September 23, 1902. Application filed January 2, 1901.

This patent is assigned to the Carborundum Co., of which the inventor is superintendent. It contains the description of a process for the utilization of the so-called amorphous carborundum, a by-product of the carborundum furnace, which is found in the carborundum furnace at the end of the operation, surrounding the core of crystalline carborundum, in a zone where the heat has not been sufficient to change it into the crystalline variety. It was customary to carefully separate it from the crystalline product and mix it with another charge of raw material. This amorphous carborundum is now, according to the patent, pressed into bricks, or other desired shapes, and subjected again to the action of the current, when it is changed into a crystalline mass of carborundum. It is claimed that in this way the bricks or other shapes, though very firm and coherent, are obtained in a considerably more porous condition than if they were molded directly out of crystalline carborundum, and are consequently more desirable for many purposes, as lining furnaces, fire boxes, etc., where they have to withstand sudden changes of temperature without cracking or disintegration. For purposes where still more porous articles are wanted, the inventor proposes to mold them from a mixture of carbon and silica in the proper proportions, and then subject them to the heat of the electric furnace, in order to convert them into carborundum, which product then is said to be more coherent and dense than the ordinary carborundum furnace product, but more porous and of less weight per volume than if it were made of compressed amorphous carborundum. For a porosity between these two grades, amorphous carborundum and a mixture of carbon and silica, as described, are mixed together in the desired proportions. It is also proposed to make such articles of carbide of boron, by molding them either directly from the amorphous material obtained in the manufacture of that carbide or from a mixture of carbon and boracic acid, and treating them in the same manner as described above. Whenever it is desired, a solution of a binding material, such as silicate of soda, glue, etc., may also be added to the mixture before compressing it, which material will be volatilized in the subsequent furnace operation. These bricks will no doubt be a valuable and welcome addition to the list of refractory materials at the disposal of the metallurgist.

*Apparatus and Processes for the Electrolytic Production of Metals and Compounds. Bleaching Apparatus.* Chauncey Cook Clark, Philadelphia, Pa. Patent No. 708,796, September 9, 1902. Application filed January 22, 1901.

The object of this invention is stated to be "an apparatus for the manufacture of bleaching material in an inclosed receptacle by electrolysis, to thereby prevent the escape of the valuable chlorine gas separated from the chloride of sodium, and assure its absorption by the inclosed liquid." The apparatus in which the electrolysis is carried out is, in appearance, almost identical with the one described by the same inventor in patent No. 706,529, of August 12, 1902, under the head of "Electrochemical Apparatus," noted on page 65, Vol. I, of this journal. The application for the present apparatus was filed on January 22, 1901, while the application for the one described in patent No. 706,529 was filed on September 20, 1901. As a consequence, the apparatus under consideration, the result of an earlier application, does not contain improvements in the mechanical construction which were embodied in the later application. All the objections which were raised to that apparatus, on page 63, Vol. I, of this journal, are applicable here. One statement is of interest, as showing how easy the problem of producing bleaching solutions is solved on paper. It is stated: "The separation being produced by a series of electrodes suspended in the salt solution, the residium comprising the impurities of the solution, as the earthy, saline, vegetable (!), animal (!), metallic matter, etc., falling to the bottom of the receptacle, where means are provided for its removal." It is a pity that the impurities cannot be so easily disposed of in the actual electrochemical practice in general, and the manufacture of bleaching solutions in particular. Instead of that, they seem to be most obstinately bent upon taking part in the decomposition and producing many undesired

and annoying complications, so that in most instances a preparatory chemical treatment of the electrolytes has to be resorted to in order to remove them.

*Electrolytically Treating Ores.* Clinton Emerson Dolbear, Boston, Mass. Patent No. 709,817, September 23, 1902. Application filed June 3, 1901.

This invention relates to "a new and improved method of producing from raw ores metallic copper or other metals by electrolysis in the wet way." The inventor describes his process as follows: "I take a body of the metal-bearing ore that is soluble in a dissolved nitrate or in nitric acid, crush it and subject it to the action of a nitrate in solution or to nitric acid mixed with sulphuric acid. The object of the nitrate or nitric acid is to furnish the nitric acid radical in quantity sufficient to accomplish the necessary chemical changes. An excess of nitric acid will not interfere with the working of the process. The sulphuric acid will not of itself attack the ore if it be in a state of sulphide or metallic copper, but in the presence of the nitric acid radical it will do so. If a nitrate be used—for instance, Chile niter (sodium nitrate)—the sulphuric acid takes the sodium from the nitrate, liberates the nitric acid radical which in its turn will attack the sulphide, dissolving the base. The sulphuric acid takes the metal from the nitric acid radical, forming the sulphate. During this process the nitric acid loses oxygen, forming nitric oxide, which, under usual conditions, will rise to the surface and be lost." The inventor then proposes to put an insoluble anode, carbon, for example, on the bottom of the electrolytic vat, stating that he can use also anodes of gold or platinum; but it is very probable that he will not use those in practice if he wants anybody to invest in his apparatus. The cathode is of the composition of the metal, to be "plated out" of the bath. The electrolytic operation is described as follows: "When current is flowing, the positive terminal will liberate oxygen, which, passing through the solution, oxydizes the nitric oxide back to nitric acid. This is then in a condition to take up more metal, react with the sulphuric acid and again go through the process just described. The current, of course, at the same time plates the metal onto the cathode, thereby in one operation giving the desired metal from the raw ore." As will be seen, it is proposed to utilize for the solution of the metallic constituents of the ore the well-known reaction used in the laboratory for the production of nitric oxide, which consists in treating copper turnings with a saturated solution of saltpeter, and then introducing concentrated sulphuric acid. The reaction takes place according to the equation:

$$3\,Cu + 2\,NaNO_3 + 4\,H_2SO_4 = 3\,CuSO_4 + Na_2SO_4 + 4\,H_2O + 2\,NO.$$

Theoretically, the reactions described as taking place in the solution and electrolysis are all possible, but, unfortunately, the reagents described will not only dissolve the principal metallic constituent of the ore, but also all the other metals present in it, a fact which the inventor unconsciously admits by claiming his process to be universally applicable to ores. If this is the case, the action of the current will not only result in "plating out" the one metal which the inventor desires to obtain, but will deposit all of them. This will be especially true in this case, as the mass of ore resting on the anodes, between the two electrodes, will of necessity increase the resistance of the solution to the passage of the current, and will prevent the application of the artifice of using a low enough voltage for decomposition f. i. in the case of copper ores, in order to deposit the copper only by keeping the voltage of the bath below the decomposition value of the salts of the other metals present. The problem of purification of the electrolyte, which seems to have been entirely neglected in the process under consideration, is a very serious one (see, for instance, the patent noted below of Tossisza). The use of nitrates as electrolytes is also more or less undesirable in practice, as they are not by any means as easily handled as the sulphates and chlorides. If the nitric acid electrolyte is not regenerated in the process, then it would be eo ipso inapplicable in practice, as the use of such an expensive reagent would be out of the question, a fact which is also emphasized by Schnabel in his "Hand-book of Metallurgy," in speaking about copper sulphide ores, where he says: "The energetic solvents, such as aqua regia, nitric acid, chlorine and hot concentrated sulphuric acid, are too dear to be applicable on a large scale." It would, moreover, seem as though a very fine crushing of the ores was necessary for the successful operation of a process like the one under consideration, a fact which would increase the cost of operation considerably. If this process has been noted in such detail, it has been done with a view of considering it as a representative of its class, bearing in mind that it is not always the theoretically most perfect process which gives the best results in practice.

*Electrometallurgic Treatment of Ores of Copper and Other Metals.* Constantin Jean Tossisza, Paris, France. Patent No. 710,346, September 30, 1902. Application filed August 6, 1901.

The inventor states that heretofore the direct electrolytic treatment with insoluble anodes of the solutions obtained by the action of sulphuric acid on previously roasted copper ores has been impracticable, because it required, before all, a complete purification of the solution obtained in order to free them from all sulphates other than the sulphate of copper. Such a purification being very difficult, the direct electrolytic treatment was, for that reason, industrially inapplicable. It is intended to overcome that difficulty by making use of the low voltage of decomposition of the copper sulphate. It is, however, very difficult in practice to maintain this low voltage of decomposition, on account of the polarization manifesting itself at the anode, and thus causing a rise of potential above the voltage of decomposition of the other salts present. Consequently the deposit, which was pure in the beginning, will be more and more contaminated with other metals as the electrolysis proceeds. The one thing to do, then, would be to prevent this polarization, and this the inventor proposes to do by introducing a depolarizer, for which he uses sulphurous acid. The anodes are made of carbon, and the sulphurous acid may be introduced either as solution or in the form of gas outside of the anode, or through the anode itself, for which purpose the anode is made hollow. The inventor says that he has ascertained that the transformation of the sulphurous acid into sulphuric acid at the anode gives rise to an electromotive force, which diminishes the necessary voltage and lowers it to two-tenths of a volt. "One can thus obtain a very beautiful deposit of pure electrolytic copper directly from an impure solution with a sufficient intensity at a voltage of about six-tenths of a volt," whereas in all processes heretofore known one could only obtain this electrolysis with insoluble anodes at voltages above 1 3-10 volts. The sulphurous acid which is used is preferably obtained from the preliminary treatment of the sulphite ores, which are roasted to produce oxides and sulphurous acid gas, which is used as such or in solution. The oxides of the metals produced are then dissolved in sulphuric acid and subjected to electrolysis. The idea of using sulphurous acid as a depolarizing agent in the deposition of copper is not new, as may be seen from Borcher's "Electro-Metallurgy," page 214, where it is stated that in Stolberg, Germany, sulphurous acid had been used for the same purpose, and that a patent for the same idea was already applied for in 1885.

*Electrolytic Decomposition of Alkaline Salts.* Edwin Edser and Meyer Wildermann, London, England. Patent No. 709,971, September 30, 1902. Application filed March 28, 1901.

This specification applies to the electrolysis of alkaline salts in those forms of apparatus in which mercury is used as a means of absorbing the alkali metal. The inventors claim that they are able to affect the decomposition of the alkali amalgam quicker than before by bringing it into contact with pieces of

carbon having part of their surface coated with a suitable electro-deposited metal.

STORAGE BATTERIES.

*Electric Accumulator Plate.* Alexander Fischer, Berlin, Germany. Patent No. 708,334, September 2, 1902.

This invention relates to improvements in electric accumulator plates, consisting of sheets of lead folded into serpentine form. The objects of the invention are, first, to stiffen the plates, and, secondly, to increase their active surface. In carrying out this invention, the sheets of lead which are to be converted into accumulator plates are bent or corrugated so as to produce a number of relatively deep parallel grooves, running from top to bottom of the plates. At the apex of each corrugation a number of tongues are cut out, thus producing openings for the passage of the electrolyte. Along the top and bottom edge of the plate bars are provided, in order to stiffen the plate laterally. The arrangement thus described constitutes the framework of the plates, which are then ready to be formed and filled with the active mass.

*Method of Manufacturing Secondary Battery Plates.* George H. Christian, Cleveland, Ohio. Patent No. 708,695, September 9, 1902. Application filed December 7, 1901.

The invention relates to the manufacture of secondary batteries, and is particularly applicable to the preparation of the spongy lead element of such batteries. The formation of the spongy lead from the peroxide is carried out either in an electrolyte composed of a solution of dilute sulphuric acid or plates provided with litharge or red lead are respectively caused to constitute the cathode and anode of an electrolytic cell, with an electrolyte consisting of dilute sulphuric acid. As a result of the electrolysis, the litharge is reduced to spongy lead, and the red lead changed to lead peroxide. Instead of conducting both these operations in an electrolyte composed of dilute sulphuric acid, the inventor substitutes an electrolyte consisting of a solution of an organic acid, such as oxalic or formic acid, or a compound of such acid with an alkaline "earth," such as oxalate of potassium, oxalate of sodium, etc. A solution of about one pound of oxalic acid in one gallon of water is used by preference. On passing the current, of preferably about $\frac{1}{2}$ ampère per square inch of plate surface, the peroxide is rapidly reduced to spongy lead. After the reduction is complete, the spongy lead plates are immersed in a bath of running water, where they are left for about twelve hours, in order to thoroughly remove the carbonic acid and oxalic acid remaining in the pores of the lead. The inventor states that by this means he has found that spongy lead plates having superior physical and electrical qualities, with less loss of active material, are produced, a wider variation in the qualities of the current used being permitted. These plates are also claimed to have a greater electrical capacity per pound of lead than other plates. It will be seen that the inventor proposes rather expensive electrolytes in place of the dilute sulphuric acid used heretofore.

*Method of Manufacturing Plates for Secondary Batteries.* George H. Christian, Cleveland, Ohio. Patent No. 708,694, September 9, 1902. Application filed December 7, 1901.

This specification is almost identical in phraseology with the preceding one by the same inventor. The only change is in the composition of the electrolyte, where, instead of a solution of oxalic acid and water, there is now substituted a solution of a compound of an organic acid with an alkaline "earth," such as oxalate of potassium, oxalate of sodium, etc., which oxalate is preferably prepared in solution with water. The same improvements as claimed above for oxalic acid alone are, of course, claimed in this specification for potassium and sodium oxalate. The first claim reads: "In the process of manufacturing plates for secondary batteries, the step which consists in electrolytically reducing an oxide of lead in an electrolytic cell having an electrolyte containing a compound of an organic reducing agent." This claim is certainly broad enough to satisfy any inventor.

*Jar for Storage Batteries.* Patrick Kennedy, Brooklyn, N. Y. Patent No. 709,157, September 16, 1902. Application filed January 6, 1902.

This application describes an improved form of receptacle or jar for the plates of storage batteries, which is especially applicable when the storage batteries are used in installations for the lighting of railway cars. The inventor provides a lining of soft vulcanized rubber, closely fitted into an outer receptacle, ordinarily made of wood. He also provides suitable protecting guards or buffers on the sides, which serve to keep the battery plates from contact with the lining. A ribbed plate of any suitable ceramic material is resting on the rubber lining on the bottom. It is claimed that this jar will withstand the jolting or shocks to which it may be subjected on the cars without rupture or cracking of the lining.

*Secondary Battery.* William L. Silvey, Dayton, Ohio. Patent No. 709,611, September 23, 1902. Application filed February 8, 1902.

This invention relates to the details whereby storage batteries may be more perfectly arranged, easier assembled and taken apart for repairs than has heretofore been possible. Any battery man of ordinary intelligence should be able to make his own repairs, and with but little necessary apparatus. It is proposed to accomplish this by doing away with the connecting bar welded to the battery plates and substitute therefor a slotted bar, to which the various plates are fastened by screw bolts. Various mechanical arrangements of the connecting bar are described at length. The greatest objection to an arrangement of this kind seems to lie in the multiplication of individual contact points, each of which is liable to get out of order, and will necessitate a great deal more watching than is necessary when the plates are welded to the connecting bar.

*Electric Separator for Batteries.* Arthur W. Harrison, Los Angeles, Cal. Patent No. 708,708, September 9, 1902. Application filed May 7, 1902.

The patent aims at providing an efficient separating medium for storage-battery plates, especially in batteries designed for use in automobiles, where it is desirable that the battery should be as light as possible, and that the electrodes should be kept perfectly insulated from each other. Corrugated sheet rubber or corrugated sheets of wood are both unsatisfactory. It is claimed that a plate separator made from yucca wood will furnish a very tough and light non-conducting separator, which permits a free circulation of the electrolyte and yet keeps the electrodes perfectly insulated from each other. The material, after being cut from the tree in the desired length and thickness, is treated by boiling it in a weak solution of sulphuric acid or caustic soda until the starch and other non-fibrous material is dissolved. It is then dried and ready for use. If the non-fibrous material is not removed, it is said to clog the circulation and interfere with the action of the battery.

*Electric Battery.* Timke Henry Klinker, Jr., and Richard Gabrielsky, Jersey City, N. J. Patent No. 710,278, September 30, 1902.

The cell described in this specification is one of the class of dry batteries. The positive electrode is formed of a sheet of zinc, constructed in such a way as to present as large a surface as possible. The negative electrode is composed of carbon, corrugated at its lower part, also in order to increase its surface. The cell is filled with sal ammoniac, which is used either alone or in combination with some other well-known material. Provision is also made for moistening the filling and thus "reactivating" the cell, by arranging conduits for that purpose in the carbon and zinc electrodes. The whole is inclosed in a casing of sheet lead, formed from one piece of material, without a seam.

MISCELLANEOUS.

*Process of Manufacturing Nitrogen Compounds from Atmospheric Nitrogen.* Charles T. Bradley and Dimmitt Ross Lovejoy, New York. Patent No. 709,867, September 30, 1902. Application filed March 19, 1900.

This patent describes the process for the manufacture of nitrogen compounds from atmospheric air evolved by Mr. Charles T. Bradley, the president, and Mr. D. R. Lovejoy, the electrician of the Atmospheric Products Co., Niagara Falls, N. Y., the works of which were described and illustrated in an article by Prof. J. W. Richards in this journal, Vol. I, pages 21 to 23. The process has proven so successful on an experimental scale that a large plant is to be built at Niagara Falls, part of which is already in process of erection. The inventors have found that the silent electric discharge is not capable of effecting nitrification to an appreciable amount, and that the ordinary spark is also of comparatively little value. In order to produce a large yield, an arc is absolutely necessary, and the best results are obtained by using a spark as thin as possible. The patent covers the process for the nitrification of air, describing also briefly the apparatus in which the nitrification is carried out. The various steps of the process are illustrated by a plan of the complete installation, as shown by Fig. 1. The atmospheric air enters into the systems of apparatus by the air inlet 58. The air entering the nitrification apparatus should be as dry as possible, in order to reduce the formation of any nitric acid in the apparatus itself to a minimum. This is said to be of advantage when the nitrous oxide and nitrogen

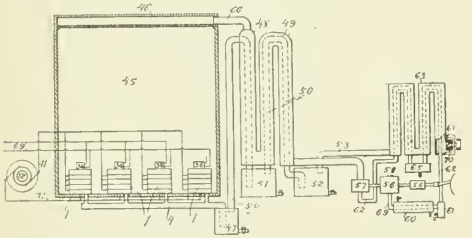


FIG. 1—FIXATION OF NITROGEN FROM THE AIR.

tetroxide are to be collected as such, and it further prevents the corrosion of the metallic parts of the nitrification apparatus. In order to obtain this, the air, after entering the system, is passed through a series of cooling and expansion apparatus. From the intake 58 it passes into a compressor 56, worked by an engine 55, whence it passes into pipe 59, cooled by water cooler 60. A trap, 61, here allows the moisture removed thus far to drain off, while the air passes on through pipe 62 into another cooler 63, where more moisture is removed by trap 65. It next enters the expansion engine 57, where it is still further cooled; and from there passes successively into two apparatuses, 49 and 48, which serve as coolers for the nitrogen compounds coming from the nitrification apparatus, and where the cooled air acts as a cooling medium in order to condense the nitrogen tetroxide and trioxide. From receiver 48 the cold, dry air passes through pipe 66 into the distributing chamber 46, arranged at the top of chamber 45, whence it enters the nitrification apparatus 36. After nitrification, it passes out by conduit 4, depositing any nitric acid which may have been formed in trap 47, and then enters successively the coolers 48 and 49. In the first one of these it is cooled to about 0° C., in order to condense substantially all the nitrogen tetroxide, which collects in the receiving vessel 51. The second apparatus is cooled still further in order to condense all the nitrogen trioxide which collects in receiver 52. From receiver 52 the gases pass through pipe 53 into cooler 63, where they again act as cooling mediums, and are finally discharged from opening 67 by blower 70, assisting, if necessary, in the circulation. It is stated that in this process the amount of nitrous products is only about 2 to 3 per cent. of the amount of air supplied, by which means the waste due to dissociation by the action of the arcs on the combination products already formed is said to be substantially prevented. The nitrous products are obtained as such, *i. e.*, as anhydrous oxides of nitrogen. In collecting the products by the use of sulphuric acid, the gases are drawn in an upward direction through a tower filled with obstructing material, over which the sulphuric acid introduced at the top of the tower trickles down. The acid absorbs substantially all the

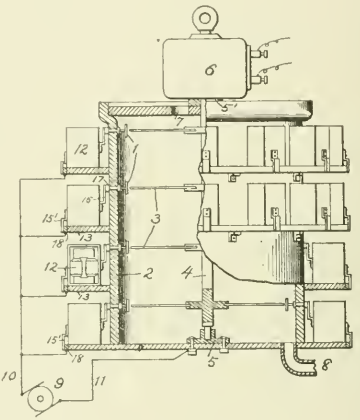


FIG. 2—FIXATION OF NITROGEN FROM THE AIR.

nitrous products, and passes then into a heated receptacle, where the expulsion of the nitrous products as vapor takes place, such vapor passing through a condensing apparatus into a suitable receptacle.

*Apparatus for Subjecting Gases to High-Tension Discharges.* Charles S. Bradley, New York, and D. R. Lovejoy, Niagara Falls, N. Y. Patent No. 709,869, September 30, 1902. Application filed March 9, 1900.

This specification describes the apparatus used in the process described above. Figs. 2 and 3 supplement Fig. 19 in Professor

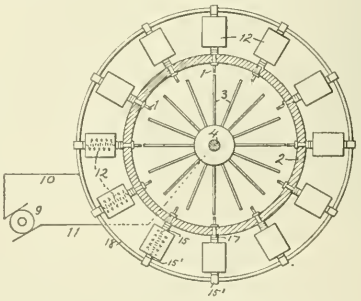


FIG. 3—FIXATION OF NITROGEN FROM THE AIR.

Richards' article, on page 21 of Vol I of this journal, and present a partly sectional elevation and a horizontal section of the apparatus. Fig. 4 represents a movable shaft, having a series of terminals 3, and connected to one pole of the dynamo 9, by means of wire 11 and bearing 5. Immediately opposite the terminals 3 are arranged opposing terminals 1, connected in parallel to the other pole of the dynamo by means of wire 10, and having included in the connection an inductance or self-induction device 12, represented as consisting of coils of wire connected in series and wound on a core of magnetic material.

To facilitate the connecting of these induction coils, they are arranged on annular shelves 13, and bear on one side by their terminal 15, against a strip 17, which is connected to terminal 1, and on the other side by their terminal 15 against a contact ring 18, connected in parallel with the other contact rings by wire 10 to dynamo 9, as noted above; 6 is the motor which revolves the shaft 4; the air enters the apparatus at opening 7, and is drawn off through opening 8. The operation of the apparatus, supplemented by a number of practical details and illustrations, is fully described by Prof. Joseph W. Richards in this journal, Vol. I, pages 11 to 23. The inventors state that the apparatus, though adapted to carry out the process of nitrification of air by exposing a current of air to the action of intermittently elongated and interrupted arcs, may also be applied to the treatment of other gases or mixtures of gases with electric discharges.

*Rotary Apparatus for the Production of Diffused Electric Discharges.* Mauris Otto, Neuilly, France. Patent No. 707,797, August 26, 1902. Application filed November 12, 1901.

This invention relates to an improved rotating machine for effecting a continuous and uniform discharge of electricity across a space through which a quantity of gas may be caused to pass in order that it may be subjected to electrical treatment. The construction of the apparatus, which is specially designed for the formation of ozone by silent discharge, is shown by Fig. 4. It consists essentially of a metallic plate *h*, which

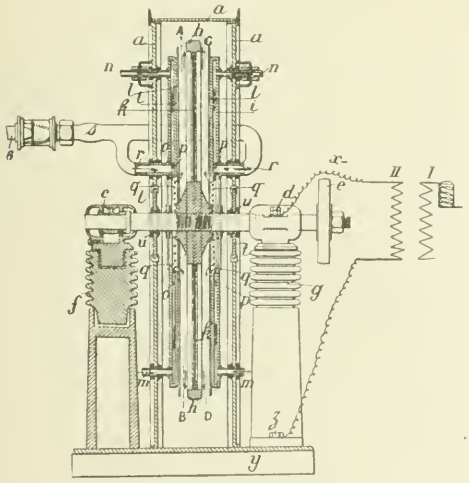


FIG. 4.—OZONIZER.

serves as one of the electrodes of the apparatus and can be rotated around an axle *b*. Opposed to it are disks *i*, one on each side of *h*, which constitute the other electrode, and are covered with an insulating film or a lining of dielectric material *l*, on the side towards the revolving plate *h*. The disks *i* are hollow, for the purpose of being cooled by cold air or refrigerated water, entering through tubes *m*, *m*, and leaving through tubes *n*, *n*. Pipe *s* supplies air to the apparatus by its two branches, which air enters the inclosed space between the movable electrode *h* and the disks *i*, and there receives the diffused discharges, which shoot across the space between the electrodes. The oxygen of the air is by this means partially transformed into ozone. I designates the primary of a transformer, at low tension, and II is the secondary, at high tension, of that transformer. The air-containing ozone is drawn off at the bottom of the apparatus.

*Ozonizing Apparatus.* Alexander Vosmaer, Haarlem, Netherlands. Patent No. 709,427, September 16, 1902. Application filed October 4, 1901.

This apparatus is also an ozonizing apparatus, of simple construction, in which the electrodes are completely independent of the casing of the apparatus in which the air circulates, and from which they can be easily removed and replaced when necessary. The arrangement consists of two electrodes placed horizontally into a tube, preferably an ordinary gas pipe. The electrodes comprise a metal bar, of any suitable metal, of square or rectangular section, in which are fixed at intervals supports of insulating material, like porcelain, having at their upper part a fork, in which rests the other electrode. The other electrode the inventor designates as the discharger, and it is provided with a number of pins or points. The current of air to be ozonized enters at one of the ends of the upper tube and passes out through the other, consequently circulating in the plane wherein the electric discharges take place. This arrangement comprises one complete unit of the apparatus, and it is obvious that the apparatus may consist of a number of similar tubes, having a common inlet and outlet. An apparatus of considerable power can thus be easily constructed by arranging the tubes in a similar manner as in the crown sheet of a boiler or a surface condenser. The easy manner in which the electrodes can be replaced constitutes one of the principal advantages of the apparatus.

## ELECTROCHEMISTRY AT THE WORLD'S FAIR, ST. LOUIS.*

By W. E. GOLDSBOROUGH.

At St. Louis there is in process of development an International Exposition in which this Society can but be deeply interested. It will be brought to completion and presented for the education of the people of our country and the world at large, just at the time when the electrochemical industries of America will be acquiring that strength which will make them a most important element in our national life. Already I have heard it said by more than one distinguished foreigner, that America is regarded as having gained an unimpeachable position and prominence in the building up of this new industry, and I cannot but think our Society hears these admissions with no small degree of pride and satisfaction.

To my mind, it is right and highly desirable that an intimate knowledge of conditions should exist between the electrochemists and the officers of the Exposition. By the officers of the Exposition I am commissioned not only to extend to you a hearty invitation to participate in their great undertaking, but to go further, and assure you that in a most helpful spirit, they extend to you assurances of their great desire to place the resources of the Exposition at your command to the end of picturing in a way that will attract international attention, the true worth and vigor of this infant industry.

In accordance with the provisions of the official classification of the Exposition, the products of the electrochemical processes will be shown in several of the exhibit buildings. Manufacturers, liberal arts, machinery, and mines and metallurgy, as well as electricity, come in for a share of these products. And, indeed, it will be proper to exhibit certain electrolytic processes in the Palace of Liberal Arts, and certain others in the Palace of Mines and Metallurgy; but to electricity, in unrestricted measure, is accorded the privilege of giving expressions to all electrochemical operations, whether purely electrolytic in character, whether brought about by electrothermic means simply, or whether attained by a combination of electrothermic and electrolytic methods.

* Abstract of a paper presented before the Niagara Falls Convention of the American Electrochemical Society, September 17, 1902.

In the Department of Electricity one of its five groups is entirely devoted to electrochemistry.

Class 434 of this group is devoted to primary batteries, and storage batteries. In this class, in addition to an exhibit of the finished products, efficiency tests of batteries will be inaugurated and a careful record kept of their performance during the period of the Exposition. In addition to these, processes in the manufacture of various types of storage batteries will, it is hoped, be arranged for, in order that this matter may be pictured in a broad way.

Class 435 embraces electrolytic appliances and processes. All forms of electroplating, methods of electrotyping, and finally and most important, the applications of electrolysis in the reduction of ores and other related work, find place here; that this class presents the possibility of a most interesting and instructive series of exhibits will be at once recognized. Electrolysis plays an even greater and more important part in the business of the world each year. It has attained to a well-recognized position. Yet, with increasing emphasis, the work we see about us here at Niagara Falls, demands for it an even broader and more important recognition.

Class 436 deals with electrothermic appliances and methods, and, therefore, includes all of the electric furnace applications which we have found pictured in the great local factories on such a large scale. Nothing is more impressive than an inspection of the actual work of the electric furnace. We are in fact almost appalled in noting the wonderful results, both in magnitude and industrial importance, which are brought about by the dissipation of electric energy by these means, and its transformation into heat. The electric arc, when applied on a large scale, attracts and rivets the attention, not only of the initiated, but the uninitiated as well. It presents the picture of power in a most fascinating way.

Class 437 deals with the application of electricity to industrial chemistry, disinfection of sewerage water, manufacture of bleaching powder, caustic soda, nitric acid, chlorate of potash, etc., etc. Much can be done to make the exhibits in this class of great value and interest, not only to students, but to engineers and chemists. Some of the most interesting electrochemical operations find expression in the field of industrial chemistry, and a strenuous effort will be made to show all of its important divisions.

With the brief outline that I have given you, you will begin to appreciate the immensity of the task which is set for those servants of the Exposition, who will bring to its full realization the hope which I entertain for the success of the electrochemical group. That all the help and assistance which you as electrochemists can offer us will be most acceptable and gratefully received, it is hardly necessary for me to say. That I ask it, is because I believe you are as deeply interested as myself in having an adequate picture of what you are doing presented to the world. In my judgment a large and fine exhibit in this group will have a most beneficial effect upon the development along electrochemical lines. If, to-day, the financiers and people of the country generally had great confidence in the ability of electrochemists to carry to a successful issue all that is rightly claimed for electrochemistry, and if "electrochemistry" had become as much of a household word among our people, as have the technical terms employed in the older and better known branches of industry, it is safe to say that the money which will be investing in and about Niagara Falls within the next few years, would from the very force of the confidence of the general public, be augmented many fold. We, at the Exposition, are not therefore attempting anything that is illogical or unreasonable, when we plan to show all of the electrochemical processes I have mentioned in actual operation, and to show as many of them as may be possible on a commercial scale.

In the Electricity Building, as you doubtless know, space will be free to exhibitors, and provision has been made to supply exhibitors with free power within reason. The installation facilities are also all that can be asked, inasmuch as the railroad lines will be extended right into the Electricity Building during the period of installation, and traveling cranes and movable hoists will be provided over all of the principal aisles in the building.

At the present time the success of the exhibits in the Electricity Department can be said to be assured, inasmuch as a large number of most interesting working exhibits have already been arranged for in the allied branches. A maximum load of 2,000 horse-power will be available for the development for the working exhibits, and without doubt the building will teem with light and activity.

Within the next two years we will have time to give the topic which has been the subject of my talk the careful attention and thought which it needs, as well as the strenuous effort and labor which its development deserves. From the interest you have been good enough to manifest in what I have said, I feel assured of your helpful co-operation and advice in this very important department of my work, and I hope I have not lead you to expect anything that will not be fully realized.

In closing, I wish to say, that the chief of the Department of Mines and Metallurgy has extended to you through me the most cordial assurances of the interest which he takes in this work. It is his desire that in all its details the applications of electricity to metallurgy shall be given the fullest expression.

## ELECTROCHEMICAL THEORIES ILLUSTRATED BY EXAMPLES FROM PRACTICE.

### FARADAY'S LAW AND THE THEORY OF ELECTRONS.

The most puzzling point to the electrical engineer when he first undertakes the study of electrochemical problems is the very important part which the valence plays in Faraday's law. As an example, the final step of the Siemens & Halske copper process consists in depositing copper from a Cu $SO_4$ solution, while the final step of the Hoepfner process consists in depositing copper from a Cu Cl solution. With the same number of ampère hours, one obtains twice as much copper from the Cu Cl solution as from the Cu $SO_4$ solution. The reason is, of course, that Cu is monovalent in Cu Cl and bivalent in Cu $SO_4$. But to someone who does not fully understand the meaning of "valence" such a statement means nothing. For a full understanding of the part which the valence plays in electrolysis, it is necessary to approach the problem from the chemical side; it is then easy to apply the chemical theory of valence to electrochemical phenomena. In this way notations and terms which appear purely formal from the chemical point of view get a very substantial meaning when applied to electrochemistry.

*Valence, Bonds.*—The notation introduced by Prof. Otis C. Johnson is particularly suitable for our purpose. While for a detailed study of his notation the reader must be referred to Prescott and Johnson's "Qualitative Chemical Analysis," we will here briefly state the fundamental points. A bond—that is, a unit of *active valence*—is either a plus one or a minus one. The oxidation of an element is shown by an increase, and its reduction by a decrease of the number of bonds. Hydrogen (in combination) has always two negative bonds. Oxygen (in combination) has always two negative bonds. Free elements have no bonds. The sum of the bonds of any compound is zero. In salts the bond of the metal is always positive. In acids and in salts the acid radical has always negative bonds. These rules enable one easily to determine the valence in any compound. For instance, in HCl, H has one positive bond, hence Cl must have one negative bond in order to have the sum of all the bonds in the molecule equal to zero. In $H_2SO_4$, $H_2$ has two positive bonds and $O_4$ eight negative bonds, hence S has six positive bonds, or the radical $SO_4$ has two negative bonds. In our example noted above we had CuCl and $CuSO_4$. In CuCl, Cl has one negative bond, hence Cu one

positive bond. In $CuSO_4$, $SO_4$ has two negative bonds, hence Cu two positive bonds. In other words, Cu is monovalent in the first case and bivalent in the second case.

Johnson has also given the following simple rule for balancing equations which represent oxidation and reduction: "The number of bonds changed in one molecule of each shows the number of molecules of the other which must be taken, the words 'each' and 'other' referring to the oxidizing and reducing agents." One example may illustrate this rule, which appears to be purely formal from a chemical point of view, while its physical meaning will be shown below. In the Bunsen cell Zn is oxidized; it becomes $ZnSO_4$. The metal Zn has no bond. Zn in $ZnSO_4$ has two positive bonds, hence the increase in bonds is two. There are several actions possible at the other electrode. We may consider that of the development of NO. N in $HNO_3$ has five positive bonds, while in NO it has two positive bonds, hence the decrease in bonds is three. Now, Johnson's rule states that we have to take three molecules of Zn and two molecules of $HNO_3$, and we get the equation

$$3\ Zn + 3\ H_2SO_4 + 2\ HNO_3 = 3\ ZnSO_4 + 2\ NO + 4\ H_2O.$$

*Faraday's Law.*—The amount of electrochemical action produced (*i. e.*, of oxidation at the anode and of reduction at the cathode) is directly proportional to the product of ampere hours and the chemical equivalent. In other words, when a certain quantity of electricity (measured in coulombs or in ampère hours) passes through a certain electrolyte, a certain definite quantity of material is reduced at the cathode and oxidized at the anode. For instance, when 96,540 coulombs pass through CuCl, we know that one gram atom Cu is deposited upon the cathode and one gram atom Cl is liberated at the anode. We may form the following mechanical scheme as an illustration of what happens in the electrolyte. We may think that the passing of an electric current from the anode to the cathode is brought about by the cations Cu charged with positive electricity and giving off their charges to the cathode, and by the anions Cl charged with negative electricity and giving off their charges to the anode. We must then assume that in this case each gram ion Cu carries with it a charge of 96,540 positive coulombs, and each Cl ion 96,540 negative coulombs. When one gram atom Cu is deposited upon the cathode, it gives off its charge of + 96,540 coulombs, and at the same time one gram atom Cl is set free at the anode and gives off its charge of — 96,540 coulombs. In other words, 96,540 coulombs are taken off from the anode and given to the cathode, with the result that 96,540 coulombs "have passed through the electrolyte."

If we have $CuSO_4$, instead of CuCl, we know from experience that when $2 \times 96{,}540$ coulombs pass one gram atom Cu is deposited upon the cathode and one gram ion $SO_4$ reacts at the anode. In this case we must assume that one gram atom Cu is charged with $2 \times 96{,}540$ positive coulombs and one gram ion $SO_4$ is charged with $2 \times 96{,}540$ negative coulombs. Cu is here bivalent, and has here twice the charge which it has in CuCl, where it is univalent. In general, *any gram ion is always charged with so many times 96,540 coulombs as it has bonds in Johnson's notation. Positive bonds represent a positive charge, negative bonds a negative charge.*

Johnson's rule of balancing equations representing oxidation and reduction becomes self evident if applied to an electrochemical action. It simply means that just as much electricity passes from the anode into the electrolyte as from the electrolyte into the cathode. In the case of equation (1), if the chemical symbols represent gram atoms or gram molecules, then, as Zn gains two bonds and as we have three Zn atoms, $3 \times 2 \times 96{,}540$ coulombs pass into the electrolyte from the anode. On the other hand, N loses three bonds, and, as two N are reduced, $2 \times 3 \times 96{,}540$ coulombs are given off to the cathode.*

* Of course, we may consider $HNO_3$ to be ionized into H and $NO_3$ ions, both univalent, etc. The result is the same as above

*Faraday's Law and the Theory of Electrons.*—We may go a step further and apply the modern theory of electrons to our problem. This has been done by Nernst. We will assume there are positive and negative electrons, although only negative electrons have so far been isolated. We may consider them as kinds of new elements (only for the sake of illustration), with so small atomic weights that, for all practical calculations, they may be considered zero; while their characteristic and distinguishing feature is that each positive electron has an electric charge of 96,540 positive coulombs, and each negative electron has an electric charge of 96,540 negative coulombs. Nernst, therefore, considers any univalent positive gram ion as a compound of the gram atom with a positive electron; also any bivalent gram ion as a compound of the gram atom with two electrons, and so on. This view emphasizes the essential difference between atoms and ions, and at the same time gives a very convenient scheme for applying Faraday's law. Johnson's bonds are, then, a very substantial thing. His positive bonds are positive electrons, and his negative bonds are negative electrons. This view, although it may be called very hypothetical, offers the safest method of applying Faraday's law. There is no possibility of making a mistake if we always keep the mechanical model in mind. Take our equation (1). As mentioned above, each Zn atom gains two bonds—that is, in our new model—while the Zn atom on the electrode has no inherent electric charge, the Zn ion in the solution (as we may consider the $ZnSO_4$ solution to be ionized into Zn ions and $SO_4$ ions) is combined with two positive electrons (because it has two bonds). Hence, if the symbols in equation (1) represent gram atoms or gram molecules, three gram atoms Zn become three bivalent ions, *i. e.*, get a charge of $6 \times 96{,}540$ coulombs. In other words, the equation (1) represents the chemical action if $6 \times 96{,}540$ coulombs pass through the system. If one only knows what the oxidation and reduction is at the two electrodes, one can calculate the whole matter. Johnson's rule for balancing equations enables one to write down the equation which represents the electrochemical action, and there is no mistake possible if one keeps in mind that each bond corresponds to 96,540 coulombs, if the chemical masses are measured in gram atoms or gram molecules.

## CURRENT NOTES.

OUR esteemed contemporary, *The Engineering and Mining Journal* announces that its chief editor, Dr. David T. Day, and its managing editor, Mr. E. W. Parker, have resigned, the former on account of the urgent demands of his work on the Geological Survey and the latter on account of the onerous work and the responsibility devolving upon him as a member of the Anthracite Coal Strike Commission. The new editor will be Mr. J. A. Rickard, with Messrs. F. Hobart, J. Struthers and S. Sanford as associate editors and Messrs. R. W. Raymond, W. R. Ingalls, J. A. Church, R. A. F. Penrose, Jr., S. F. Emmons, W. H. Weed, P. Argall, A. G. Charleton and D. J. Day as "special contributors."

THE eighty-third meeting of the American Institute of Mining Engineers was held in New Haven, Conn., from October 14th to 17th. The list of members and guests registered comprised about 60 names. (At the last Niagara meeting of the much smaller American Electrochemical Society about 160 members and guests had registered.) Some 20 papers were read, partly in title. Among the papers read was one by Dr. Leonard Waldo, on the measurement of high furnace temperatures, in which he pointed out the many important applications of the pyrometer. Visits were made to the Yale University, and especially the Peabody Museum, and a geological excursion was made to West Rock.

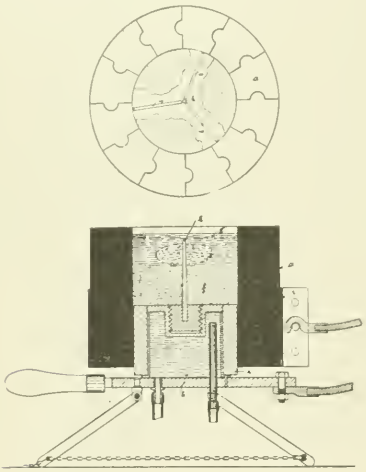
# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

By Carl Hering.

## INDUSTRIAL ELECTROCHEMISTRY.

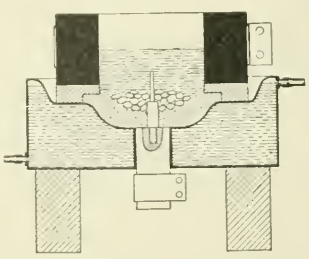
*Metallic Calcium.*—The production of calcium from its compounds by electrolysis has generally been considered to be very difficult, and it is therefore of some interest to see that Borchers and Stockem have succeeded in producing metallic calcium from some of its compounds, on such a scale that the process is claimed to be applicable on a commercial scale. The



Borchers and Stockem Calcium Furnace.

question naturally arises, what is to be done with this metal, which is not now used in that form? But, like in other similar cases, the reason why it has not been used is probably because it was not a cheap commercial article, and when it becomes so good uses for it will no doubt be found. Their process is described, with illustrations, in the *Zeit. f. Elektrochemie*, October 2, 1902. They have found that it is quite easy to deposit large quantities of calcium, by electrolysis, of electrically-fused calcium chloride, which is free from water. They use a small cathode opposite a large anode, and keep the temperature at a red heat above the melting point of calcium chloride, but below the melting point of metallic calcium; the calcium is then deposited at the cathode in a spongy form. This sponge forms such a coherent mass that it can be easily removed from the cell. If the sponge is then at once put into a suitable liquid, free from oxygen, one obtains a sponge of 50 or 60 per cent. free metallic calcium, mixed with calcium chloride. If the sponge is pressed before it is removed from the cell, it welds itself into a dense, bright mass, containing about 90 per cent. of calcium. Instead of calcium chloride, other calcium salts, especially calcium fluoride, may be used. The addition of calcium fluoride to calcium chloride has no unfavorable action; the authors prefer to use calcium chloride because it is cheap, and it has such a melting point that by exceeding it slightly one at once obtains that temperature which is best for the formation of the coherent sponge without necessitating careful temperature measurements. If the temperature is raised beyond the melting point of calcium, there are unnecessary heat losses and a tendency to re-dissolve the deposited metallic calcium, presumably by the chlorine gas. The apparatus used by the authors is shown in the adjoining diagram. The case, containing the fused salt, is the cylinder *a*, which consists of carbon rods put together like the pieces of wood of a wooden barrel, and held together by a metallic ring *r*. This forms the anode and connection to the external source of current made through the metallic ring *r*. The cylinder is closed at the bottom by a cooling apparatus *h*. The cathode consists of an iron rod *k*, placed into the cooling apparatus, the frame of the latter forming the connection with the negative pole of the source of current. The iron cylinder *a* and the cooling apparatus *h* are, of course, separated from one another by an insulating layer *i* of clay or other suitable refractory material. The lower part of the case is filled with compressed calcium fluoride *f*, the greatest part of which remains solid during the operation, on account of its higher melting point, and because it is cooled from *h*. In this way the fused chloride of calcium is protected against coming into contact with and receiving impurities from the bottom of the case. Above the fluoride there is placed the calcium chloride *c*. In order to fuse it and to start the process, several thin carbon rods *x* are provided, which short-circuit the cathode *k* with the anode carbon cylinder. When the circuit is closed, the current melts the top of the calcium chloride, after which the rods *x* are removed and the electrolytic operation is started. They mention briefly that in afterwards treating the calcium thus produced, they obtain crystals which seem to be CaCl.

*Pure Strontium.*—These same experimenters have also shown how pure strontium may be produced in a very similar way, the illustrated description being in the same number of that journal. It is a short article, in which they say that they have succeeded in using this calcium apparatus, just described, with a slight modification, for the production of pure strontium in large quantities. By electrolyzing electrically-fused strontium chloride in their calcium apparatus, they obtained metallic strontium, not in the form of sponge, but in form of fused globules, of about the same specific gravity as the bath. Much strontium was mechanically transfused to the anode, and this represents losses, causing a poor ampère-hour efficiency. The apparatus was therefore modified, as shown in the adjoining

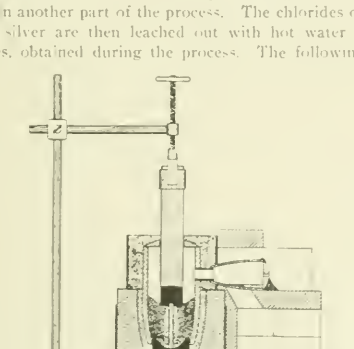


Borchers and Stockem Strontium Furnace.

diagram. The cathode, which was an iron rod, passes up from below through the cooling apparatus, but only to such a height that it is about at a level with the carbon cylinder, which forms the anode and rests upon an insulating ring, which separates it from the cooling apparatus. The bottom of the case is filled with a solid mass, with a pit in the center part, in which the strontium deposited at the cathode in form of globules remains

at rest and becomes solid, as it is cooled from below. In the lower part of the solid mass globules of pure metallic strontium are found, of diameters up to 10 mm., after the electrolysis is finished. Strontium is, like calcium, a white metal, and just as soft as lead.

*Reducing Zinc from its Ores.*—The production of zinc from its compounds involves difficulties due to the very electropositive nature of that metal, or, to put it into more modern terms, on account of the high value of the energy of combination of zinc compounds. In electrolysis this means the use of such high voltages that other undesirable reactions take place, for which that voltage is more than sufficient. In aqueous solutions, for instance, hydrogen is liberated much more easily than zinc. Such processes are therefore of special interest; all the more so as the electric methods have not yet come into use as much as might be expected. In a recent article in the *Zeit f Elektrochemie*, September 25, 1902, DANNEEL describes several zinc processes which were worked out at the metallurgical laboratory of the Institute of Technology of Aix-la-Chapelle, Germany. The first one is devised by Borchers, the director of the laboratory, and Dorsemagen. They chlorinate raw ore in the presence of salt solutions, such as sodium chloride and magnesium chloride, in revolving iron drums, lined with lead, at a temperature of 30° to 40° C., by means of free chlorine, obtained in another part of the process. The chlorides of lead, zinc and silver are then leached out with hot water or hot dilute lyes, obtained during the process. The following data



DORSEMAGEN FURNACE FOR THE PRODUCTION OF ZINC AND SILICON CARBIDE.

of a test are given: 1,000 kg. ore contained 140 kg. lead, 310 kg. zinc, 0.69 kg. silver. There were chlorinated and leached out 140 kg. lead, 175 kg. zinc, 0.11 kg. silver. In the residue there remained 135 kg. zinc, 0.53 kg. silver and 115 kg. sulphur. After the extraction of the sulphur, there remained a residue of 39.1 per cent. zinc and 0.168 per cent. silver. From the residue, the sulphur is removed by Schaffner's method under steam pressure. The chloride lyes are purified by means of zinc oxide or roasted zinc ore, evaporated to dryness and dehydrated as completely as possible. The dehydrated mixture of chlorides is then electrolyzed in a fused state, and at the anode the chlorine gas is obtained which is used in another step of the process, as mentioned above; while at the cathode a mixture of molten lead and zinc is produced, which is obtained in two alloys—lead poor in zinc and zinc poor in lead. From the lead which is poor in zinc, the zinc can be removed by steam; the zinc which is poor in lead is refined by distillation. A large experimental plant for studying this process on an industrial scale is being installed by F. Krupp.

The second process described was devised by Borchers and von Kuegelgen, and is for treating the waste from zinc galvanizers. This waste is dissolved in hydrochloric acid to saturation. The iron is removed from the solution by means of chloride of lime and other oxidizing agents; it is then evaporated to dryness in iron crucibles lined with lead. The pulverized zinc chloride is mixed with metallic oxides—for instance, copper oxide and calcium carbide—and is then melted to zinc alloys—for instance, brass. The reaction between zinc chloride, metallic oxide and calcium carbide goes on by itself, flowing to its own heat of reaction, after the reaction has been started by means of an incandescent body; but to obtain good metal it is necessary to heat the crucible.

The third process described was devised by Dorsemagen, for the treatment of siliceous zinc ore, especially if the percentage of zinc is small; zinc and silicon carbide (carborundum) are produced. An electric furnace is used, as shown in the adjoining diagram. A mixture of carbon and siliceous zinc ore is heated in the furnace by a carbon rod; the zinc is distilled off, and there remains silicon carbide. The reduction temperature of the silica is only slightly above the distillation temperature of zinc.

The fourth process described is by Borchers and Dorsemagen, and is quite analogous to the last one described. It is used for the treatment of ores containing iron and zinc, in order to get ferrosilicon and iron. The process differs from the last one only in so far as ferrosilicon, instead of silicon carbide, is obtained.

*Lead Refining.*—Lead is being refined from its bullion by the Betts process, in a plant having a capacity of about 10 tons daily. It is said to have a low working cost and a high efficiency. This plant is described by ULKE in the *Engineering and Mining Journal*, October 11, 1902. The general arrangement of the plant is very similar to that of a copper refinery. The success of the process is based upon the solubility of lead in an acid solution of lead fluosilicate, which has both stability under electrolysis and high conductivity, and from which very pure lead is said to be deposited with impure anodes at a very low cost. The solution is obtained by diluting hydrofluoric acid of 35 per cent. H. F. with an equal volume of water and saturating it with pulverized quartz. The anodes consist of the lead bullion to be refined, cast into plates about 2 inches thick. The cathode sheets, which receive the regular lead deposits, are thin lead plates, obtained by electrodeposition upon and stripping from special cathodes of sheet steel. The anodes and cathodes are separated by a space of 1.5 to 2 inches in the tank; the tanks are in series; the fall in potential between tanks is only 0.2 volt. Current densities of from 10 to 25 amperes per square foot have been used, but 14 amperes have given the most satisfactory results. According to the inventor, "260,000 ampere hours at 0.25 volt works out to 87 electric horse-power hours, or 100 horse-power hours at the engine shaft, in round numbers. Estimating that 1 horse power hour requires the burning of 1.5 pounds of coal, and allowing, say, 60 pounds for casting the anodes and refined lead, each ton of lead refined requires the burning of 210 pounds of fuel." Practically all the impurities in the base bullion remain as a more or less adherent coating on the anode, and only the zinc, iron, cobalt and nickel practically go into solution. The anode residue consists practically of all the copper, antimony, bismuth, arsenic, silver and gold contained in the bullion, and very nearly 10 per cent of its weight in lead. The silver slimes obtained, averaging about 8,000 ounces of gold and silver per ton, are now treated at the Seattle Smelting and Refining Works.

*Copper Depositing.*—A description of the Dessolle process of copper plating, in which the electrolyte is projected under pressure against the metallic object and the anodes, is published in a recent number of the *Journ. Soc. Chem. Ind.*, an abstract of which may be found in the *Lond. Elec.*, October 3, 1902. The metallic objects are first cleansed, either in an acid bath or by means of a jet of sand driven by compressed air, which rapidly removes all impurities. They are next placed in a preparatory bath and subjected to the action of a current of 30 amperes per square meter. The composition of this so-

called "adhesion bath" is as follows: Double cyanide of potassium and copper, 4 parts; potassium cyanide, 0.5 part; ammonia, 0.5 part; water, 94 parts. On leaving this bath, the objects are carefully examined, and any trifling holes in the deposit stopped with solder, or, if larger, with spongy tin, obtained by electrolysis. They are next immersed in the principal bath, which has the following composition: Crystalline copper sulphate, 12; free sulphuric acid (65 degrees), 3; water, 85 parts. Jets of this liquid are driven against the surface and that of the anodes. This effects a removal of gas and impurities from the bath and enables a strong current to be used, so that a perfectly smooth deposit of copper is obtained. In Dessolle's installation a current with an ampèrage of 750 is employed, and a deposit of 1-10 mm. is obtained in one and one-half hours, a rapidity of deposit which is stated to have no prejudicial effect upon the quality. The temperature is maintained at the required degree by means of steam jets, viz.: at 50° C. in the adhesion bath and at 35° C. in the final bath. The electrolyte projected by the jets falls into a central tank below, whence it is raised by means of wooden pumps to a reservoir fixed at a height of 5 meters above the level of the bath, and falls through the jets again under considerable pressure. Finally, the plated articles are dried and polished in the usual way. The price of plating metals with a good deposit of copper does not exceed 2 fr. per kilogramme of deposit, but the economic advantage of the Dessolle process is that there is perfect adhesion of the deposit, which can be made thicker and yet be durable.

There is another, but very short, article on the use of copper deposits to hold together pieces of glass, by forming a sort of beading on the edges of copper strips placed between the edges of the pieces of glass or prisms, by which means composite structures, like reflectors or refractors, are built up. The method seems to be used in place of the usual burned lead strips in colored-glass windows. It is very briefly described in the *Lond. Elec. Rev.*, October 10, 1902.

*Manufacture of Aluminum.*—A Bunsen Society paper, in which Haber describes a series of experiments to show on a small scale the principal points which are of importance for the success of the manufacture on a large scale, is given in the *Zeit. f. Elektrochemie*, August 21, 1902.

*Graphite.*—The change of amorphous carbon into graphite was known to have occurred at the high temperature of the arc, but it was not until Acheson discovered the necessary intermediate action that it became possible to succeed in doing this commercially. He showed that to bring about the change it was necessary to first form some compound of carbon and then dissociate this, setting free the other element. The carbon which remains will then be in the form of graphite. Danneel, in the *Zeit. f. Elektrochemie*, September 25, 1902, gives an account of an investigation of this transformation by Borchers and Moegenburg. They found, as Acheson did, that this conversion is very difficult when absolutely pure carbon is used, but it is greatly accelerated if metals or metallic compounds are present which are able to form more or less dissociable carbides. During dissociation the metal is evaporated, and the carbon remains as graphite. They have studied the use of iron, manganese and aluminum for this purpose, and have found that iron is least suitable, while aluminum is the most convenient and effective material. Although the reduction temperature of aluminum oxide is somewhat above that of manganese oxides, yet aluminum is more volatile than manganese. The quantities of aluminum or aluminum oxide required are relatively small. Aluminum is even considerably more effective than boric acid, phosphoric acid, etc.

*Chlorates.*—J. B. C. Kershaw's second article on electrolytic manufacture of chlorates is published in the *Elec Rev.*, October 11, 1902. In this part he discusses the Corbin cell and the Franchot and Gibbs cell, and makes some remarks on the efficiency of the various processes. He gives an estimate of the cost of chlorate of potash, made in a 3,000 horse-power hydroelectric plant, producing 1,600 metric tons of chlorate. The cost per pound of chlorate is 4.7 cents. He then gives a summary of numerous laboratory investigations bearing on the theory of chlorate cell. Foerster, Mueller and Jorre state that the reduction of the cathode can be suppressed either by use of calcium chloride or of potassium chloride. The electrolyte should be slightly acidified to liberate hypochlorous acid. A large volume of electrolyte should be used, and should be kept in vigorous agitation, in order to allow the secondary reactions to occur as rapidly as possible. The temperature of the electrolyte should be maintained above 40° C. to promote circulation, to reduce the e. m. f. and to diminish the formation of perchlorates, which otherwise would occur. Tucker and Moody electrolyzed calcium chloride solutions, and recommended that the solution should be one of 20 per cent.; the electrodes should be of platinum, horizontal, and 10 cm. apart; the current density should be 8 ampères per square decimeter at the anode; the temperature should be maintained at 80° C.; sodium chromate or sodium hydrate should be added to the electrolyte. Foerster and Mueller state that the best efficiency is obtained when an electrolyte is used containing sodium chromate and free hydrochloric acid, in conjunction with a spongy platinum electrode. Under these conditions, two-thirds of the chloride present in the cell can be converted into chlorate, with a current efficiency averaging over 94 per cent.

*Calcium Carbide Patents.*—It is certainly a tribute to electrochemistry when an article which was almost unknown only a few years ago is now manufactured in Europe in such large quantities that it becomes necessary to force a market for it in some other country by annulling the patent in that country, yet, according to a report in the *Lond. Elec. Rev.*, October 10, 1902, this is what the United Carbide Factories of Nuremberg, Germany which is presumably the carbide trust of Germany, have decided to try to do with the Willson patents here in the United States. The European and American patents are discussed at some length.

*Alizarine Industry.*—Alizarine was formerly obtained from the root *Rubia Tinctorum*, but, since Grabe and Liebermann discovered that alizarine is a derivative of anthracene, it has been manufactured from coal tar by treating anthracene with sodium bicarbonate and sulphuric acid. This gives anthraquinone, and, according to the modern process, this is treated with fuming sulphuric acid, and the monosulphite is found with caustic soda. To obtain anthraquinone from anthracene, sodium bicarbonate is necessary. Up to the present the methods for recovering the chromium salt contained in the mother liquor as chromium sulphate have been very troublesome. The electrolytic recovery has hitherto been hindered by the fact that a diaphragm is necessary between the two electrodes, and that none was found capable of withstanding the strongly acid solution for any length of time. This difficulty is said by Simon, in the *Jahresber. Phys. Ver.*, Frankfort, 1902, to have been overcome by Leblanc's invention of diaphragms, consisting of 25 per cent. alumina and 75 per cent. silica, which not only are very durable, but also have a low resistance. One German aniline dye factory has been transferred to the neighborhood of Augsburg, where sufficient water-power is available to yield a cheap supply of electrical energy for the new process. An abstract of the article may be seen in the *Lond. Elec.*, October 3, 1902.

## THEORETICAL AND EXPERIMENTAL.

*Electrolysis of Fused Sodium Hydroxide.*—Although NaOH is usually an end product of electrolysis, and not a raw material for electrolytic conversion, yet it is of interest to know what will occur when it is electrolyzed. In the *Zeit. f. Elektrochemie*, September 11 and 18, 1902, Le Blanc and Brode give a long account of an experimental investigation of this, the principal results of which may be summed up as follows: Fused sodium hydroxide containing water has two distinct values of decomposition voltage, 1.3 and 2.2 volts. In baths which are free from water, the lower decomposition

voltage disappears. By quantitive measurements of the gases developed during electrolysis at different voltages, they found that both values of the decomposition voltage have a real meaning. At 1.3 volts there is a development of hydrogen and oxygen, while at 2.2 volts sodium and oxygen are set free. The ampère hour efficiency of the oxygen increases with increasing current density. Below 2.2 volts the efficiency of the development of hydrogen is 100 per cent. as long as no free sodium is present. In a bath free from water, and with a voltage above 2.2 volts, the cathode deposition is only sodium. It is certain that pure fused sodium hydroxide contains no H or O ions, but only Na and O H ions, the latter producing water and oxygen by secondary reaction. The phenomena of the electrolytic production of sodium by the Castner process on a large scale are also discussed

*Electrolysis of Alkaline Chlorides.*—Foerster and Mueller give a long account of a series of experiments in the *Zeit f. Elektrochemie*, August 28 and September 4, 1902, the main results of which are as follows: If equimolecular solutions of alkali hydrate, hypochlorite and chloride are electrolyzed with increasing voltage, the passage of a certain current takes place through the hydrate solution at the lowest anode potential and through the chloride solution at the highest anode potential. At an intermediary anode voltage, characteristic for the electrolysis of hypochlorite, a discharge of univalent negative Cl ions take place. At the moment of the anodic discharge univalent negation Cl ions react with water and form chlor e acid, hydrochloric acid and a development of oxygen at the anode. The anodic formation of chlorate takes place as well with solutions containing free hypochloric acid as with neutral or alkaline solutions of hypochlorites. A secondary formation of chlorate takes place in the electrolysis of the hypochlorite if the electrolyte has become somewhat rich in free hypochlor ons acid.

*Electrolytic Reduction of Nitric Acid.*—An investigation of the alterations which nitric acid will undergo by electrolysis in the neighborhood of the cathode, when considerable amounts of sulphuric or hydrochloric acid are present, is described by Tafel in the *Zeit. f. Anorgan. Chemie*, 31, 3, p. 289, 1902, an abstract of which is given in *Science Abstracts* for September, 1902. He found that a reduction will occur with most cathodes, excepting, for instance, platinum. The mean products of this process are ammonia and hydroxylamine, their ratio depending on a whole series of factors and varying to a high degree, according to the nature of the cathode, whereas the sulphuric and hydrochloric acids do not seem to exhibit any marked differences. The largest amounts of hydroxylamine are evolved with pure mercury cathodes or well-amalgamated electrodes, the formation of ammonia being almost wholly prevented in some cases, so as to obtain a nearly perfect quantitative transformation of nitric acid into hydroxylamine salt; whereas in the case of lead cathodes the amount of the acid transformed into hydroxylamine was not higher than 40 per cent.; for copper, 15 per cent. at the most. The rate of this reduction is smallest in the case of copper electrodes. It is next shown that, with electrodes giving rise to this reduction process, hydroxylamine sulphate will equally be reduced, and *vice versa*.

*Ozone.*—The electromotive behavior of ozone has been studied experimentally by Inglis, an account of which is given by Luther in a recent Bunsen Society paper, published in the *Zeit. f. Elektrochemie*, August 28, 1902. In this description Luther gives nine results obtained with an ozone electrode; that is, an electrode of platinized platinum in a solution of ozone. He found that such an electrode assumes a higher oxidation potential when the electrode was previously charged with hydrogen, and a lower one if thus saturated with oxygen. He also shows an experiment which at first sight seems very strange, as there is reduction at both electrodes, and this is contrary to one of the first principles of electrolysis, namely, that there is always oxidation (or, better, "perduction") of the electrode or the solution, or both, at the anode and reduction at the cathode. The reduction at the anode in this exceptional case is explained as a secondary action, due to a primary oxidation with a formation of a higher oxide, which is, at the same time, a more energetic reducing agent. This explanation seems quite a reasonable one.

*Electric Double Layer and Absolute Potential.*—As we cannot connect a measuring instrument, which is usually of metal, with an electrolyte without using two electrodes, it follows that all measurements of electrolytic potentials give only the algebraic sum of the two potentials at the two electrodes. It seems very difficult to find some way of measuring each separately, although several more or less doubtful methods have been suggested. It is evident that the algebraic sum of two quantities can never define the two quantities themselves, as they may both be very large or very small and yet have the same algebraic sum. Sometimes the so-called hydrogen electrode is taken as zero, from which the potential difference of any other individual electrode with an electrolyte can be determined, but this is, of course, an arbitrary scale and not an absolute one. Billitzer has attacked the problem in a different way. As described in his recent Bunsen Society paper, published in the *Zeit. f. Elektrochemie*, August 28, 1902, he endeavors to find the conditions under which the potential difference between an electrode and an electrolyte is zero. It is based upon Helmholtz's theory of the relation between potential difference and electric "double layer," or, in German, "Doppelschicht." In the discussion which followed, it was pointed out that Helmholtz, starting from the same foundation, devised another method, and that Ostwald's and Billitzer's methods, although based upon the same grounds, give very different results. The whole matter is therefore, unfortunately, still entirely in the dark. Haber called attention to another method, which had been proposed by the late Luggin Nernst proposed to consider the whole matter as hypothetical, and to use a convenient, although arbitrary, zero point by assuming the potential difference at the hydrogen electrode equal to zero.

*Free Ions.*—An account of an experimental investigation into the existence of free ions in aqueous solutions of electrolytes is given by Olsen. After some critical remarks on an older experiment by Ostwald and Nernst, he describes some experiments which he has made, and which are based on the following considerations: It is believed that an electrostatic charge attracts and repels the unlike and like charged ions respectively; and as it is the ions which, in giving up their charge, produce a current, then, if these ions can be guided by an electrostatic charge, we should get a current with electrodes indifferent to the solution, and be able to detect it with a sufficiently delicate galvanometer. The results of the experiments are given as follows: When a cell containing an electrolyte is connected to a Danneel element, although the e. m. f. is below the decomposition value of the electrolyte, the solution in the neighborhood of the anode becomes positive, or, in the neighborhood of the cathode, becomes negative, or both. After an electrolyte has been electrolyzed by a current, it is affected by an electrostatic charge in such a way that the liquid nearest the charge becomes of the opposite sign, or the liquid farthest from the charge becomes of the same sign as the charge, or both, *i. e.*, an electrolyte, after having been electrolyzed, acts as if it contained particles charged with electricity, which are free to move and may be directed by an electrostatic charge. An electrolyte subjected to an e. m. f. less than the decomposition value of the solution behaves in a similar way. Finally, an electrolyte which has never been acted upon by a current also behaves in a similar way when acted upon by an electrostatic charge, *i. e.*, it behaves as if it contained particles charged with electricity, which are free to move, and these particles have not been produced by a current. This corresponds to the definition of free ions. The paper is published in the *Am. Jour. Sc.*, October.

## MISCELLANEOUS.

Among the other recent articles may be mentioned one by [illegible] on the application of electrochemical methods to the determination of the structural formulas of silver salts, in the *Zeit. f. Elektrochemie*, September 4, 1902; a Bunsen Society paper by Zsigmondy, on colloidal solutions, chiefly on the order of magnitude of the dimensions of the particles, and especially of gold, in the same number. An illustrated description by Jorris of a mercury bath for lecture-room purposes, for showing the vapor tensions of solvents and solutions by means of a series of barometer tubes, which is also in the same number of that journal.

## PRIMARY AND SECONDARY BATTERIES.

*The Prospects for a Light Storage Battery.*—In the opinion of Norden, the lead accumulator has been so much improved in recent years that there is not much room for further progress, and the "light accumulator of the future" must be a non-lead accumulator. In his article, which is published in the *Centralblatt f. Accum.*, August 15, 1902, he first discusses former trials with metals different from lead. The zinc lead peroxide cell has a higher ampère hour capacity per pound of weight, and its discharge voltage is higher than 25 per cent. But the disadvantage is that during discharge the zinc goes into solution, and during charge it is not so perfectly and cleanly redeposited, but sometimes in spongy form, which may cause short circuits, and it is therefore impossible to avoid irregularities entirely. Moreover, local action at the zinc plate cannot be entirely avoided, in spite of amalgamation. What is said here about the zinc electrode is generally valid for any soluble electrode, as in practice there will always be trouble in redepositing the metal. He therefore claims as a general principle that a soluble electrode is unsuitable for a storage battery. He then discusses the cuprous oxide zinc accumulator, in which there is again the same trouble with the zinc. The copper plate also has disadvantages; it ought to be insoluble in the electrolyte, but at the end of the charge cupric, instead of cuprous, oxide is often formed. And as soon as a trace of cupric oxide goes into the solution, copper becomes an ion, and is deposited on the zinc, causing a fatal local action at the zinc plate, as it there forms a short-circuited copper-zinc couple. It has often been concluded that the use of two different metals is therefore impracticable in an accumulator, but this conclusion would be wrong, for if both metals are absolutely insoluble there would be no danger whatever. Moreover, the last-discussed disadvantage occurs only when the metal which is dissolved can be deposited upon the opposite pole. This is, for instance, not the case with the zinc, as it never can be deposited upon the opposite plate. He therefore claims, as a second principle, that two different metals in an accumulator are practical only when they are either both insoluble in the electrolyte or when, if dissolved, they cannot be re-deposited on the opposite plates. He then discusses the Edison accumulator, which he considers to be a step in the right direction, although he does not think that it represents the definite solution of the problem of the light accumulator. The mechanical construction, with the active material compressed in perforated boxes, is not thought to be the best construction for utilizing the total active mass, as the passage of the current into the interior of the boxes and the diffusion of the electrolyte into the pores is somewhat difficult. He thinks that the capacity of the Edison cell per pound of weight is too nearly of the order of magnitude of that of the lead cell. A new principle has not been found in the invention of the Edison accumulator, but its general importance is that it shows that with an old method, which has already been considered as being without prospects, some success can be obtained. He finally points out the impossibility of predicting anything concerning the probable future development from a purely theoretical point of view.

*Tribelhorn Storage Battery.*—It is an old device to make up a series of batteries by making the cells in the form of metallic dishes piled one over the other, with insulating separators, so that the lower surface of the upper dish is one electrode and the upper surface of the lower dish is the other electrode, the liquid being filled into the dishes. This idea, although ingenious, seems to have survived only in the Tribelhorn accumulator, made in Switzerland, and said to be used in factories, hotels and central stations. Its characteristic feature is the arrangement of the cells, which are in the form of leaden conical dishes, one above the other (quite similar to Salom's arrangement for lead reduction, recently described in these columns). The upper side of each dish is positive, the lower negative. The novel device is that the active material is keyed in peculiarly-formed furrows on both sides of the dishes. The charging voltage increases to 2.75, and the discharge voltage decreases to 1.85 at slow discharge and to 1.72 at fast discharge. The ampère-hour efficiency averages 90 to 92 per cent., and the watt-hour efficiency 68 to 70 per cent. The description, with illustrations, may be found in the *Elek. Neu. Anz.* for October 1, 1902.

*Accumulators.*—The *Centralblatt f. Accum.*, September 1, 15 and October 1, 1902, contains continuations of the descriptions of the accumulator exhibits at the Dusseldorf Exposition by the following German firms: E. Schulz, of Witten; the Pollack Accumulator Works, of Frankfort; also an exhibit by the "Accumulatoren Fabrik A. G. Hagen," on sanitary arrangement in storage-battery factories.

*E. M. F. of Ozone Cells.*—An account of an investigation of the question whether the heat produced by the decomposition of ozone—which, according to Berthelot, is 29,600 gram calories per 48 grams of ozone—can be utilized wholly or in part for the production of electrical energy is given by Brand in the *Ann. d. Phys.* No. 10, 1902, abstracted in *Lond. Elec.*, October 10, 1902. A Grove gas battery can be constructed with oxygen and ozone as elements, the current passing from the oxygen electrode through the electrolyte to the ozone electrode. To determine how much of the energy is thus transformed, it was necessary to find the e. m. f. of the cell. But, since the e. m. f. of an oxygen cell is not constant, the e. m. f. of the oxygen electrode and of the ozone electrode were determined separately by comparison with a normal mercury electrode, consisting of mercury covered with mercurous sulphate and immersed in normal sulphuric acid. Eventually the author obtained an amount of energy equal to 0.5 joule per coulomb. The total work of ozonization amounts to 0.642 joule per coulomb, so that there is a rather high electrical efficiency.

*Standard Cells.*—A German Bunsen Society paper, by Cohen, on the changes of the cadmium amalgam in Weston cells under certain conditions, and on the electromotive behavior of cadmium amalgams, is given in the *Zeit. f. Elektrochemie*, August 28, 1902.

## GENERAL AND MISCELLANEOUS.

*Magnetic Concentration.*—Hassreidter gives a description of the Mechernich system of magnetic concentration in the *Jour. Soc. Chem. Ind.*, September 30, 1902, an abstract of which will be found in the *Eng. and Min. Jour.*, November 1, 1902. The ore is delivered by an adjustable chute between two magnetic poles, the upper one of which (the north pole) is rotated. As the ore arrives in the magnetic field, the permeable particles are attracted by the north pole, and are carried around by it into zones of progressively diminishing intensity, until the centrifugal force imparted to the particles overcomes the magnetic attraction and they fall into collecting chutes, being classified according to their magnetic properties. The non-magnetic material falls directly into a chute close against the lower pole. This arrangement is claimed to have the advantages of dispensing with belt carriers, which weaken the magnetic field; and also of permitting the use of small magnetic fields and very narrow air spaces, thus minimizing the loss of energy and making it possible to attract feebly magnetic

particles by a very weak current. The rotating pole being the only moving part of the machine, the wear and tear is very small. In separating blende and siderite from the Upper Harz, the grains being of 0.5 mm. size, 98.7 per cent. of the zinc has been recovered. With dolomitic Silesian blende of 2 to 3 mm. size, the recovery was 91.8 per cent., which was increased to 93.5 per cent. by reducing the grains to 2 mm. In treating ore from Broken Hill, a yield of 81 per cent. of the lead and 60 per cent. of the zinc was obtained. A plant of this type installed at Broken Hill for the treating of middlings, assaying 28 per cent. zinc, 10 per cent. lead and 9 ounces silver per ton, furnishes a product with 44 to 45 per cent. zinc and 4.5 per cent. lead.

*Electrochemistry at the Dusseldorf Exhibition.*—DANNEEL, in the *Zeit. f. Elektrochemie*, September 25, 1902, begins a long illustrated descriptive article, in the introduction of which he describes the geology, minerals, coal mining, ores and mining installations in general in the few western provinces of Germany from which most of the exhibitors come. He then discusses the exhibits of the Aix-la-Chapelle Institute of Technology, and describes several metallurgical processes which have been worked out in its metallurgical laboratory. Abstracts of these descriptions will be found in other paragraphs of this synopsis.

*Analysis of Foodstuffs.*—An article by MEDICUS, giving an account of experiments made by Mebold on the electrolytic determination of traces of metals in foodstuffs, is given in the *Zeit. f. Elektrochemie*, September 4, 1902.

## SOME EUROPEAN ELECTROLYTIC POWER PLANTS.

By FRANK C. PERKINS.

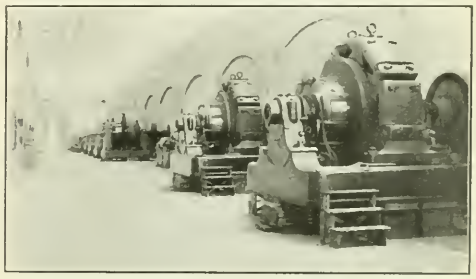
The water-powers of Switzerland which have been developed have been very extensively used for electrolytic work. The Swiss electrical manufacturers, as Brown, Boveri & Co., of Baden, and the Compagnie de L'Industrie Electrique, of Geneva, as well as the firm of Ganz & Tarsa, of Buda-Pesth, Austria-Hungary, have designed many special machines for electrolytic purposes. Among the important power plants using Swiss apparatus for the production of chlorate of potash may be mentioned those at St. Michel, Vallorbes and Cheddes, and for soda and chlorine the Usine de Gavet-Clavaux and the Usine de Monthey, Switzerland.

The Usine de Cheddes supplies the necessary power for the electrochemical production of chlorate of potash, and is located in the valley of Chamonix, the water-power being obtained from the river l'Arve, near Mont Blanc. The power house contains four Thury 8-pole direct-current generators, which operate at a speed of 240 revolutions per minute, and supply a current of 800 ampères at a potential of 700 volts. These machines were constructed by the Compagnie de l'Industrie Electrique, of Geneva, and each has a capacity of 560 kilowatts. The turbines which are directly coupled to the dynamos have a total capacity of 3,200 horse-power, or 800 horse-power each, and were built by Brenier-Neyret, of Grenoble.

The Usine de St. Michel also supplies power for the manufacture of chlorate of potash, and is located so as to take advantage of the water-power from the river l'Arc. The water conductors are 1.2 meters in diameter, and carry from 5 to 6 cubic meters, the head being about 90 meters. In this power house of St. Michel there are 12 Thury 6-pole continuous current generators, each driven by a 160 horse-power turbine of the Brenier-Neyret type. These dynamos supply a current of 500 amperes at a potential of 200 volts. There are also four 12-pole Thury direct-current machines, each supplying 1,500 ampères at a pressure of 200 volts. These machines are driven by four 450 horse-power turbines, built by A. & H. Bouvier, of Grenoble.

This same form of Thury 12-pole direct-current machine has also been employed at the Usine de la Praz for the reduction of aluminum. These machines supply 3,000 ampères at 110 volts, and operate at a speed of 250 revolutions per minute. This plant at La Praz utilizes a total of 8,600 horse-power, and is operated by the Société Electro-metallurgique Française. There are two machines at this plant, each of which supply 7,500 ampères at a potential of 35 volts, the speed being 300 revolutions per minute.

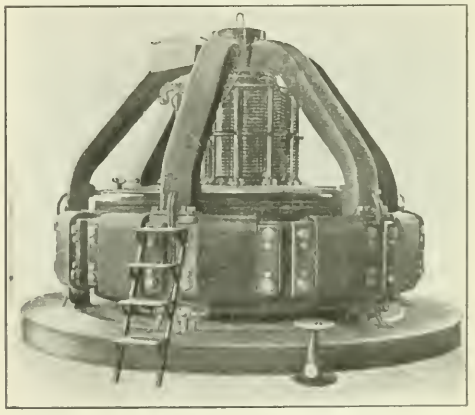
The Usine de Gavet-Clavaux is located in the valley of Bourg-d'Disan, near Grenoble, and supplies current for the production of soda and chlorine. There are two Thury 12-pole



POWER PLANT AT CHEDDES.

generators in this plant, each furnishing a current of 5,000 ampères at 75 volts, or 150 volts pressure. They are driven by four turbines of the Brenier-Neyret type. The products of the electrochemical plant at Monthey, Suisse, are noted for their purity. The sub-station at Monthey is equipped with two motor generators, the motors of which are three-phase machines, operated by a 5,000-volt current, which is transmitted a distance of 8 kilometers from the power station at Bex, Suisse, which is equipped with four 400-kilowatt three-phase machines. These two synchronous motors each have a capacity of 350 horse-power, and drive 6-pole Thury continuous-current machines, which supply 2,000 ampères at 120 volts pressure for the electrolytic work.

The electrolytic generators mentioned above have all been of the horizontal direct-current type, and before taking up the



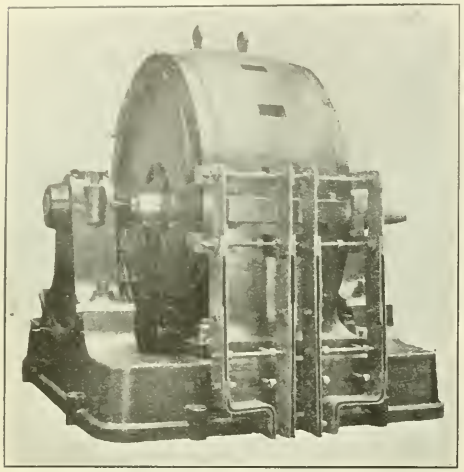
VERTICAL GENERATOR AT CHEVRES-GENEVE.

alternating current machines for the operation of electric furnaces it may be of interest to consider some of the vertical continuous-current machines used for electrochemical work.

At the Usine de la Volta, at Chèvres-Genève, Suisse, there is in operation a 12-pole Thury vertical generator, which is directly coupled to a 1,200 horse-power turbine, built by Escher,

Wyss & Co. This machine, noted in the accompanying figure, is driven at a speed of 120 revolutions per minute, and supplies a current of 4,000 ampères at a potential of 208 volts. The moving part of this machine weighs 27,500 kilograms, the total weight of the machine being about 60 tons.

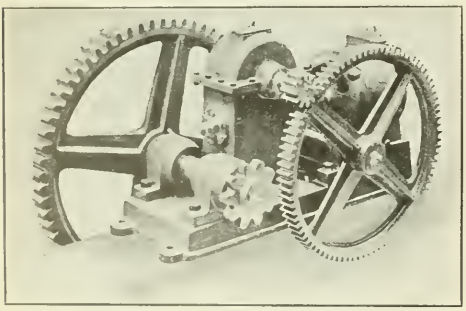
The vertical machine at Harpsborg, built by the Compagnie de l'Industrie Electrique, operates at a speed of 180 revolutions



1,500 HORSE-POWER THURY "CARBURE" ALTERNATOR.

per minute, giving 5,000 ampères at 112 volts. This machine is operated by a 750 horse-power vertical turbine.

The Thury "Carbure" alternator was designed especially for use with electric furnaces for the production of carbide of calcium. The accompanying illustration shows one of these machines of 1,500 horse-power, designed to be operated at a speed of 500 revolutions per minute. It is of the inductor type, there being no windings upon the rotating portion, and the heavy conductors bolted together may be noted in the illustration. This is a single-phase machine, and weighs 32,300



ELECTRICALLY-OPERATED WINDLASS.

pounds. It is 2,720 mm. long, 2,900 mm. high and 2,720 mm. wide. Thury has supplied a 1 horse-power three-phase motor, of 47½ cycles, for an electric windlass to regulate the carbons of the furnaces for the production of calcium carbide. This motor operates at a speed of 1,350 revolutions per minute on a 110-volt circuit, and drives the windlass or carbon regulator by means of the gearing shown in the accompanying illustration. The Société Electrochimique de la Romanche, near Grenoble, have their plant equipped with five of the Thury alternators, each of which has a capacity of 1,200 horse-power and operates at a speed of 350 revolutions per minute.

In Italy the Société Italienne pour la Fabrication du Carbure de Calcium, of Rome, have a very large power plant, using Thury alternators for the production of calcium carbide. The total capacity of this plant is 4,580 horse-power.

Ganz & Co., of Buda-Pesth, installed a number of inductor alternators at the plant at Bozen-Meran, and the current from these machines is used extensively in the works for the production of carbide of calcium. This plant is equipped with six turbines, of 1,200 horse-power each, directly coupled to 1,000-kilowatt three-phase alternators. One of the machines supplies a current of 12,000 volts pressure for long-distance transmission, and two of the alternators supply a three-phase current of 3,600 volts pressure, while the remaining two machines generate currents at both 12,000 volts and 3,600 volts potential. For use in the carbide plant, step-down transformers reduce the potential to that required.

## CORRESPONDENCE.

### MR. COWLES' PIONEER WORK.

*To the Editor of the Electrochemical Industry.*

Sir:—I have read the biographical sketch of the life of Alfred H. Cowles in the Electrochemical Industry for October, 1902. I have been and am now counsel for the Electric Smelting and Aluminum Co. in their patent litigation in relation to the manufacture of carborundum. I note in the biographical sketch the reference to the carborundum business is left as though there were doubts as to the carborundum being manufactured in accordance with the process discovered by the Cowles brothers. In justice to Mr. Cowles, I send you a copy of the opinion of the United States Appellate Court, which sat in your city some time over a year ago and passed upon the questions here involved. This decision was the final decision of the highest court. On page 11 of the opinion which I send you, you will note that it was found that the court had "no doubt on the evidence that carborundum can be, and has been, produced under the process covered by any one of the claims of the process patent in suit" (No. 319,795). "So long ago as 1884 the Messrs. Cowles produced it under their process, with and without the use of prepared or preformed central core of resistance material." Samples of carborundum were left by the Messrs. Cowles at the museum of the Institute of Technology in Boston at these early times, and during the course of this case the samples were produced and proven as having been made by the Messrs. Cowles years before Mr. Acheson began to experiment with the Cowles furnaces.

I note the word "said" is used in the same questionable manner in relation to the Cowles' work having opened up the development of calcium carbide. If you care to take the trouble to communicate with Mr. Edward N. Dickinson, Washington Life Building, New York City, the attorney for the Electric Gas Co. and Union Carbide Co., you will be able to learn that these two companies recognized the priority of the Cowles brothers in this field and are licensees under the Cowles patents, though it is a fact that Mr. Edward M. Dickinson was also the attorney for Mr. Thomas S. Willson.

Francis C. McMillin,
*Solicitor and of Counsel for*
*The Electric Smelting and Aluminum Co.*
Cleveland, Ohio.

[We would regret exceedingly if the phraseology referred to by Mr. McMillin should convey to the minds of our readers generally any lack of recognition or any sense of depreciation of the splendid pioneer work of Mr. Alfred H. Cowles. The article in question was written at the request of the editor by one who has an intimate knowledge of the career of Mr. Cowles, and the qualifications were introduced merely because the expressions affected were explicit statements of fact beyond the knowledge of the editor, and which, since the article bore

no signature, would, without such qualification, have gone on record as facts within his knowledge. To this confession of a lack of that omniscience which tradition assigns to the editor must be joined a keen regret that the time at our disposal did not permit of an inquiry, the results of which would surely have strengthened, rather than weakened as Mr. McMillin would believe—a tribute to one who stands so pre-eminent in the field of electrochemistry.—ED.]

## BOOK REVIEWS.

LEHRBUCH DER ANORGANISCHEN CHEMIE. By Dr. H. Erdmann, Professor of the Institute of Technology of Berlin. Third Edition. 788 pages, with 291 illustrations, 93 tables and six colored tables. Brunswich: Friedrich Vieweg & Sohn, 1902. Price, 15 marks.

To those who read German, are *conversant* with chemistry and wish a concise presentation of the present condition of descriptive inorganic chemistry, including the most recently discovered facts, this fine volume is heartily recommended. Its appearance is attractive, with its fine paper, clear, black print, well-executed engravings, exhaustive table of contents and well-prepared index. The six colored spectrum plates are beautifully executed, and a pocket contains some loose sheets carrying logarithms, constants for calculations of analyses and commonly-used constants, which are very convenient to have at hand.

The treatment of the various chemical compounds is systematic, well balanced and thorough. The synonyms, in old style German, French, English and Russian, are given for all important compounds (Latin might have been added). The most recent discoveries in the condensation of gases, rare gases of the atmosphere, electric furnace compounds, radioactive substances and spectrum investigations are referred to more or less fully, and the information brought up to date in a very commendable manner. In some places the work of foreigners, particularly of Americans, is not accorded the relative importance which it deserves, but that is easily pardonable in a text-book intended for German students—one could hardly expect to find it otherwise.

Turning to the other side of the question, the use of the book as a "Lehrbuch der Anorganischen Chemie," we cannot speak of the volume with such high praise. If the aim of a "Lehrbuch" is simply to fill a student full of facts to make him acquainted with the very latest discovered information, and to feed him upon several half-fledged modern theories, which he is to swallow whole without asking too many awkward questions, then the book may be styled a success. But if a text-book is intended to teach a student to reflect upon chemical fact; to draw from them by logical inferences their most probable hidden meaning; to reason from cause to effect, and from given conditions to probable results; to understand, in short, the esoteric doctrines revealed only to those who search for truth with enthusiasm and a clear, open mind, then this book is, as such a text-book, a lamentable failure.

We cannot but view in the popularity of such a book as a text-book in the German schools a distinct decadence in the teaching of chemistry. The book is singularly free from the plain presentation of simple chemical facts and the deduction of evident conclusions therefrom. In this respect it is immeasurably inferior to Mendelejeff's splendid "Principles of Chemistry." It is appallingly devoid of statements of facts or principles of chemical energetics. The rich domain of thermochemistry, so pregnant with suggestions and explanations of the *why* and *wherefore* of chemical reactions, is practically omitted. In this respect it is immeasurably inferior to Ditte's excellent "Traité elementaire de la Chimie fondee sur la Thermochimie." The relations of electrical energy to chemical energy, their mutual convertibility and the bearing of this on chemical theory and its importance for the progress of chemistry are so scantily touched on as to be almost undiscoverable. What electrochemistry is given in the book is explained in a manner showing that the writer of this part was ignorant of some of the most elementary principles of electrochemistry. His explanations are often misleading, and unworthy of a mere tyro in the science. These are not random statements, but are provable by numerous quotations which could be made.

Concerning the plain, simple principles of chemistry, the book reflects the modern German practice of making a theory and then twisting or distorting one's intelligence in efforts to prove it true, overlooking or ignoring facts which prove it false. This is all the reverse of the true didactic spirit, which should be the soul of every text-book. When the author states, for example, in his preface, that "the so long puzzling difference between metals and metalloids now lies clearly before us, and shows that our old masters had a just intuition in laying these two principal divisions at the base of their division of the elements," we are prepared to find the matter cleared up completely in the text. We find the metalloids therein defined, however, as "elements partly gaseous or easily volatile, partly fixed or infusible, conducting electricity and heat poorly, and not so well cold as hot, and lacking metallic luster." If we now suppose that the unhappy student siezes on this halting definition as something a little better than nothing, how are we to imagine his frame of mind when, among 21 elements thereafter named as metalloids, five are described by the author himself as of "perfect metallic luster!" The book abounds in inconsistencies of a similar nature, which may not, it is true, mislead the chemist who uses the book and who can accept such statements at their real value, but where is meanwhile, our hapless student, who comes to his text-book to be taught.

The great industry and knowledge of the author are proven by the mass of useful information condensed in the book, but the absence of true "teaching quality" in the book, and therefore its distinct inferiority as a *text-book*, are no less plainly in evidence.

JOSEPH W. RICHARDS.

THE OPTICAL ROTATING POWER OF ORGANIC SUBSTANCES AND ITS PRACTICAL APPLICATIONS. By Dr. Hans Landolt, assisted by Dr. O. Schoenrock, Dr. P. Lindner, Dr. F. Schuett, Dr. L. Berndt and Dr. T. Posner. Second edition. Authorized English translation with additions by Dr. John H. Long. 751 pages, with many illustrations. Easton, Pa.: The Chemical Publishing Co. Price, bound in cloth, $7.50.

For those familiar with the second German edition of this work, brought out in 1898, very little need be said, except that the translator has done eminent credit to his work. In general it may be noted, however, that the subject-matter is very happily arranged, and the eye of the reader will readily catch the method of classification that is followed.

The text is introduced without needless historical retrospect or, in fact, any at all; and the symbols, formulæ and equations that are used throughout the book are explained in the first pages instead.

It may be stated that a book devoted so much to theoretical considerations, as this is, should contain as much matter of a practical nature as is given here. For, besides the considerable amount of space devoted to polariscopes and saccharimeters, very complete methods of optical sugar analysis, determinations of camphor, nicotine, cinchona alkaloids, cocaine, etc., are described in detail. The methods for the determination of the sugars are given concisely, yet as complete working methods; and although they are the official methods of the German Government, they are nearly universally adaptable and, we may say, acceptable. For additional methods, the reader is referred to United States Treasury Department bulletins and to other American and English sources.

The only thing that might be said adversely in criticism is

that it would be appropriate for a book of this kind to be better [illegible] especially [illegible] But such a considera- tion is [illegible] the value of the material that is [illegible] the cover.

The work is divided into the following parts: I: General Conditions of Optical Activity. II: Physical Laws of Circular Polarization. III: Numerical Values for the Rotating Power. - Specific Rotation. IV: Apparatus and Methods for the Determination of Specific Rotation. V: Practical Applications of Optical Rotation. VI: Constants of Rotation of Active Bodies. From this it will be seen that the book will appeal very generally to the large body of scientific workers.

## BOOKS RECEIVED.

A Text-book of Inorganic Chemistry. By Dr. A. F. Holleman. Rendered into English by Herman C. Cooper, Ph.D., with the co-operation of the author. New York: John Wiley & Sons. 458 pages, with 84 illustrations. Price, $2.50.

Elementary Chemistry. By F. W. Clarke and L. M. Dennis. New York: American Book Co. 340 pages, illustrated. Price, $1.10.

Vorlesungen ueber Theoretische und Physikalische Chemie. By J. H. van't Hoff. Braunschweig: Friedrich Vieweg & Sohn. Vol. I: Die Chemische Dynamik. 251 pages, illustrated. Price, marks, 6. Vol. II: Die Chemische Statik. 148 pages, illustrated. Price, marks 4. Vol. III: Beziehungen zwischen Eigenschaften und Zusammensetzung. 130 pages, illustrated. Price, marks 4.

Acht Vortraege ueber Physikalische Chemie, gehalten auf Einladung der Universität Chicago, 20 bis 24 Juni, 1901. By J. H. van't Hoff. Braunschweig: Friedrich Vieweg & Sohn. 81 pages, illustrated. Price, marks 2.50.

## ELECTRIC LABORATORY FURNACES.

In the following we give a description of some new forms of electrochemical furnaces which are now being put on the market by Eimer & Amend, New York City, and which are specially designed for chemical work in the qualitative, quantitative and metallurgical laboratories. It is thought that these forms of furnaces will be found extremely useful and convenient for laboratory work, as they give the highest temperatures required, are perfectly controllable and absolutely clean.

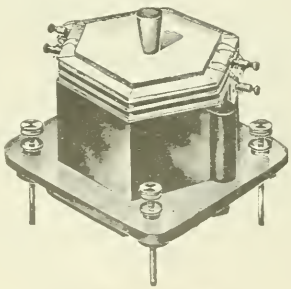


FIG. 1—HEXAGONAL FURNACE.

There is no reduction or oxidation by gases.

The special advantages claimed for these new types of electric furnaces over other electric furnaces are that they are strong and compact, and are built in sections, so that all parts can readily be replaced in case of accident. They are operated at the ordinary electric light pressure of 110 volts, and are not liable to get out of order. The further advantages of these furnaces are that the inside surface is made of smooth material, which does not crumble or crack, and the substance treated can readily be observed. The platinum ware used in these furnaces will last twice as long as in the old-fashioned blast lamp methods. The temperature in these furnaces ranges up to 1,500° C. (2,700° F.); in fact, to the melting point of platinum.

The following are the standard types and sizes: A furnace of square cross section is built in two sizes; the smaller size takes the regular-shape platinum crucibles of 10, 15 and 20 cc. capacity, the available inside space being 1 to 1½ inches by 1 to 1½ inches, the current required being 10 ampères and the voltage 110. The larger size, for 30, 40, 50 and 60 cc. platinum crucibles and Eimer & Amend's new carbon determination apparatus, has an inside space of 2 x 2 inches, the current required being 12 ampères and the voltage 110.

Fig. 1 shows an extra large hexagonal furnace, as used by Professor Landolt and Professor Traube, in Berlin, and others for atomic weight determinations, etc. It has room for

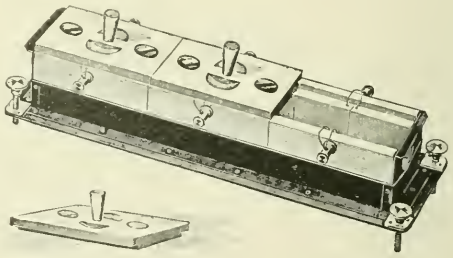


FIG. 2—SECTIONAL COMBUSTION FURNACE.

two platinum vessels for check work, etc., the current required being 15 ampères and the voltage 110.

A muffle-shaped furnace, with front shelf, is made in two sizes. The large size has an inside space width of 3⅛ inches; depth, 3⅛ inches; height, 1½ inches. It takes all regular platinum, incinerating milk and other flat platinum dishes, as well as medium-sized wasting dishes, scorifiers, cupels, etc., the current required being 12 ampères at 110 volts. The smaller size has an inside space of 1¾ inches in depth, 1 inch in width and 11 to 16 inches in height. It is used for determining the fusing point of metals, minerals, enamels and for other small thermic work, the current required being 7 ampères at 110 volts.

Fig. 2 shows a sectional combustion furnace for tubes up to 1 inch diameter, the heating surface being 15 inches in length. The current required is 10 to 15 ampères at 110 volts. This furnace permits of progressive heating from rear to front end, and *vice versa*.

Eimer & Amend also sell an electric furnace of the Moissan type in improved form. The size of the inside space is 6 x 5½ x 5½ inches. It is perfectly adjustable and accessible for experimental arc work, and requires a current of 100 ampères at 50 to 60 volts.

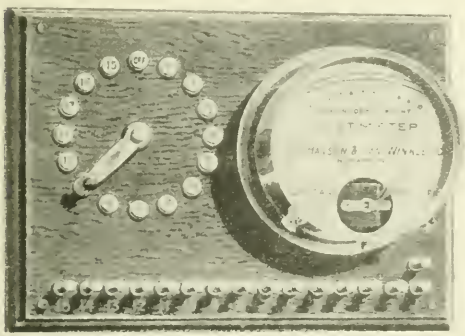
For measuring the whole range of temperature in these furnaces, the improved Le Chatelier's pyrometer, with electric couples with double wires of platinum rhodium, is very suitable. The pyrometers, as placed on the market by Eimer & Amend, are correct indicators of temperature from the normal up to 1,600° C. (3,000° F.), and are tested by the German Reichsanstalt. They are provided with a double scale, a direct reading temperature scale in degrees centigrade up to 1,600, as well as a millivolt scale.

Messrs. Eimer & Amend have also placed on the market an electric heating apparatus for distilling ether from glass vessels without danger. It is provided with a regular Edison incandescent lamp for 110 volts, and is furnished in two sizes, the one for pint flasks and the other for quart flasks.

## VOLTMETER FOR ELECTROPLATING PLANTS.

Great progress has been made in recent years in the methods of electroplating. By careful observation, the practical electroplater has studied the chemical composition of those solutions which are best adapted for obtaining a certain metallic deposit, and at the same time he has learned by experience what are the best electrical conditions—especially the best current density—for obtaining a satisfactory deposit of uniform thickness in the shortest space of time. After he has found once the best electrical conditions, it is only necessary that he should be enabled to reproduce them easily and safely at all times. For this purpose it is of the greatest importance that either the electromotive force between anode and cathode, or the current flowing through the bath, be accurately measured. The ordinary galvanometer is insufficient, and often misleading. Experience has shown that only the very best voltmeters or ammeters should be used in electroplating plants. They should be so constructed as to indicate quickly and accurately any sudden changes in current, and should be direct reading in volts or ampères; and their indications should not be subjected to gradual changes. A sensitive voltmeter will indicate the slipping of belts, short-circuiting in tanks and any irregularity in the power supply.

The adjoining diagram shows the Starrett improved voltmeter, made by the Hanson & Van Winkle Co., Newark, N. J., for the special use of electroplaters. These voltmeters have a



VOLTMETER FOR ELECTROPLATING PLANTS.

scale from 0 to 6 volts and upwards. The scale is divided into 120 divisions, so that each division represents 0.05 volt, and, when in connection with the switch board, the voltmeter enables the plater to study carefully all the requirements which insure good results.

These voltmeters are of the permanent magnet type, and by the process of treating the magnets the manufacturers have succeeded in insuring the permanence of the magnets for years without any appreciable change, unless placed within a powerful magnetic field. For this reason they should not be placed close to a dynamo, nor should a current be passed through them in a reverse direction, as this has a tendency to demagnetize the magnet.

These instruments, as made by the Hanson & Van Winkle Co., are furnished with binding posts for fifteen tanks, thus enabling the operator to use one instrument for any number of tanks up to fifteen by means of a shunt, from which the wires run to each tank. The operator simply moves a switch, and by this arrangement, and in connection with the switch board, he can easily control the voltage for each tank and the current passing through it. It is evident that this arrangement greatly simplifies the methods for exactly reproducing the electrical conditions required for obtaining satisfactory results.

## PERSONAL.

MR. D. R. LOVEJOY, of the Atmospheric Products Co., Niagara Falls, N. Y., has recently sailed for Europe.

DR. R. OGDEN DOREMUS, New York City, recently resigned from the presidency of the Greater American Mining Co., New York.

MR. WILLIAM C. NICHOLS, president of the Nichols Chemical Co., copper refiners, of New York, recently visited the Granby Consolidated Mining, Smelting and Power Co's mines and smelter in the Boundary District of British Columbia.

COL. ALLAN C. BAKEWELL, recently elected president of the Sprague Electric Co., was for the past three years the second vice-president and general manager of this company. In his place, Mr. M. D. Clarence Durland has been elected second vice-president, who, for the last three years, has been assistant general manager of the company.

DR. A. E. KENNELLY has recently returned to Philadelphia from a cable-laying trip in Mexican waters, and has taken up his duties as professor of electrical engineering in Harvard University.

DR. JOHN F. KELLY, of the Stanley Electric Co., has just returned from a long trip abroad.

**American Electrochemical Society.** — The following-named gentlemen have been elected members at the directors' meeting, held November 6th: Erik W. Tillberg, Worcester, Mass.; Geo. W. Patterson, Jr., University of Michigan, Ann Arbor, Mich.; A. V. Knudson, New York; Arthur E. Kennelly, Harvard University, Cambridge, Mass.; C. S. Bradley, New York; Walter T. Taggart, Philadelphia, Pa.; Barthold E. Schlessager, Boston, Mass.; Max Mauran, Niagara Falls, N. Y.; W. E. Goldsborough, Lafayette, Ind.; C. C. Speiden, Summit, N. J.; F. B. Crocker, New York; Charles J. Green street, Fort City, Pa.; Ashmead G. Rodgers, Niagara Falls, N. Y.; F. J. A. McKittrick, Schenectady, N. Y.; Wm. O. Mathews, Dover Bay, Ohio; E. A. Deeds, Niagara Falls, N. Y.; A. T. Lincoln, Urbana, Ill.; J. G. Zimmerman, Madison, Wis.; James L. Ervin, Washington, D. C.; Geo. O. Knapp, Chicago, Ill.; C. E. Freeman, Chicago, Ill.; Charles F. Vaughn, Niagara Falls, N. Y.; Harold Childs Pease, Schenectady, N. Y., and Fritz Haber, Karlsruhe, Germany.

## INDUSTRIAL NOTES.

We have received from Messrs. Baker & Co., Newark, N. J., the tenth edition of their handsomely-illustrated pamphlet, "Data Concerning Platinum." It gives illustrated descriptions of the various types and forms of platinum crucibles, dishes, pans, muffles, spatulas, triangles, filter cones, combustion boats, spoons, electrodes, tweezers, tongs, retorts, baskets, pots, platinum tips for lightning rods, platinum gauze, etc. Some valuable information is given on the use and care and on the cleaning of platinum ware. Special notes refer to platinum stills for the concentration of sulphuric acid and to platinum protective fuses for telegraphic and telephonic work. Several tables at the end of the book will be greatly appreciated by the practical man. They give the weight per foot of platinum wire in troy weights and grams; also the weights per square inch of platinum sheet or foil. Other tables give the number of square inches of platinum sheet and foil per troy ounce, the weight per foot of platinum wire in troy ounces and the number of feet of platinum wire per troy ounce. There are also comparative tables of length, areas and volumes; tables of specific gravities and melting points, a comparative table of wire gauzes, sulphuric acid tables, etc.

THE C. W. HUNT CO., West New Brighton, N. Y., inform us that at the Dusseldorf Exhibition, which has just terminated, the highest award of merit, the gold medal, was awarded to their Hunt conveyor.

# DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

*Compiled by Byrnes & Townsend, Patent Lawyers.*
*National Union Building, Washington, D. C.*

*This digest of electrochemical United States patents prior to July, 1902, will be one by classes, setting out for comparison in each class those devices which have the same object, or those methods which seek the same results. In each class the patents will be arranged chronologically. The digest will be complete in the sense of covering every point which is touched upon in the original specification.*

DIAPHRAGM CELLS FOR THE PRODUCTION OF CAUSTIC ALKALI.*

415,644. November 19, 1889; Georg Kerner, of Frankfort, and Julius Marx, Ulm, Germany.

Electrolyzes sodium chloride or "mixed salts of the alkalies or alkaline and other earths, it being known that the current decomposes these salts in a definite order, so that the several bases and acids can be obtained separately." The electrolyte may be heated or cooled. The anode and cathode products are kept apart by a diaphragm, and removed by precipitation or otherwise. When electrolyzing sodium chloride, the dissolved chlorine is removed "by exhausting or drawing, or by forcing air through the apparatus." Says that sodium chlorate gradually accumulates in the solution and is decomposed by the addition of potassium chloride, giving potassium chlorate. When sulphates are electrolyzed, removes the sulphuric acid from the anode compartment by the addition of calcium carbonate, phosphate or chloride. Converts the caustic soda produced in the cathode compartment into a bicarbonate by the injection of carbon dioxide; or may add magnesium carbonate or carnallite to produce a double carbonate, or may produce a double carbonate of sodium and zinc. Afterward decomposes the sodium bicarbonate with caustic soda. Decomposes the double carbonates by boiling or passing steam through them. May effect the precipitations in the electrolytic cell or in separate vessels, returning the residual liquors after enriching them with salt. Causes the anode and cathode solutions to flow in opposite directions, to diminish loss by re-combination.

442,334. December 9, 1890; Isaiah L. Roberts, Brooklyn, N. Y.

Anode, a compressed mixture of retort carbon and ozokerite. Surrounds anode by a mass of finely-divided anthracite coal, held in a bag of cotton, strengthened by asbestos or wire gauze. Gaseous anode products and any overflow escape through a layer of granular carbon and a lateral pipe at the top of the bag, the neck of which is sealed by asphalt or tar. Iron vessel serves as cathode.

442,396. December 9, 1890; Isaiah L. Roberts, Brooklyn, N. Y.

Electrolytic vessel, consisting of an inner and outer wooden box, with an intermediate space filled with tar or asphalt. Walls of anode compartment of glass or slate. Diaphragm of asbestos cloth, between asbestos boards, and inclosed in cotton cloth, the whole treated with sulphuric or hydrochloric acid. Anodes of carbon, or an alloy of lead, antimony and mercury. Cathode, copper.

442,494. December 9, 1890; Isaiah L. Roberts, Brooklyn, N. Y.

Apparatus similar to 442,334, except that a glass cylinder extends from the neck of the bag down into the packing of coal dust.

450,103. April 7, 1891; Ernest Arthur Le Sueur, Ottawa, Canada.

Vessel, a shallow open tank, containing a number of anode bells of stoneware. Each bell is closed at its lower end by a diaphragm of vegetable parchment, beneath and in contact with which is the cathode, consisting of a number of sheets of wire gauze riveted together. One rivet of each cathode extends down into a mercury cup in the bottom of the tank. Cathode connections lead to each mercury cup. A single cathode may underlie all the bells. The tank may be of iron, and also act as cathode. Each bell is supported in the tank in a slightly inclined position, to facilitate escape of hydrogen from the cathode. Each bell is nearly filled by an anode consisting of a large number of carbon rods, secured at their upper ends in a lead plate and extending down nearly to the diaphragm. Through each bell pass supply tubes, which dip into the electrolyte, and an outlet for chlorine.

450,104. April 7, 1891; Ernest Arthur Le Sueur, Ottawa, Canada.

Inclined anode bell of earthenware, supported on the bottom of an open tank. Lead tubes pass through the top of the bell, and serve both as supports for the anode and conduits for introducing brine and removing chlorine. Lower end of bell closed by a diaphragm and wire gauze cathode. Diaphragm clamped to lower edge of bell by a metal ring, within which sufficient hydrogen accumulates to press diaphragm against lower edge of bell, preventing leakage. Electrolyte in bell maintained at a somewhat higher level than outside. Automatic device cuts off electric current in case the diaphragm ruptures.

468,880. February 16, 1892; Ernest Arthur Le Sueur, Ottawa, Canada.

Anode bell has an outer overflow passage to indicate level of liquid within. Anode supported in bell by a central stem, having a passage for introducing brine. Upper end of stem surrounded and supported by an inverted cup, having sealed chlorine outlet. Cup supported on bell by adjusting screws or wedges.

480,491. August 9, 1892; Elisha B. Cutten, New York, N. Y.

Vessel of iron serving as cathode. A horizontal glass plate near bottom of vessel supports a glass trough, within which is a carbon bar imbedded in insulation. Vertical anode rods, arranged in a row, are screwed into the carbon bar at their lower ends. End of carbon bar extends out through vessel and carries anode terminal. A transparent glass bell incloses upper ends of carbon rods. An annular sheet-metal hood fills the space between sides of the vessel and bell, its flanges dipping into the electrolyte. A pipe for removing hydrogen leads from this hood to a suction pump. A pipe for removing chlorine leads from glass bell to a suction pump. A body of solid salt is maintained within the vessel, resting on the glass plate near the bottom and extending up to the upper ends of the anode rods. An inclined gutter at the bottom of the vessel serves to remove caustic. A passage for the introduction of strong brine extends through the carbon anode bar, and branch ducts open up between each pair of anode rods. Inside of iron vessel coated with varnish to a point below lower edge of glass bell. May electrolyze calcium or magnesium chloride.

481,407. August 23, 1892; Farnham Maxwell Lyte, London, England.

Production of caustic alkalies and chlorine. First, produces sodium ferrate, nitric oxide and oxygen by heating a mixture of sodium nitrate and ferric oxide; second, boils the ferrate with water, producing caustic free from iron and ferric hydrate; third, decomposes the ferric hydrate by heat, producing ferric oxide, which is returned; fourth, produces nitric acid by adding air and water to the nitric oxide and oxygen from the first reaction: fifth, combines the nitric acid with litharge to produce lead nitrate; sixth, decomposes the lead nitrate with sodium chloride, producing lead chloride, which is melted and electrolyzed, and sodium nitrate, which is returned. Converts the electrolytic lead into litharge, which is returned.

*(To be continued.)*

* For a critical analysis of the problem the reader is referred to the article of C. P. Townsend on page 23 of the September issue of this journal.

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## STORAGE BATTERY INVENTION AND MANUFACTURE.

In this issue we print several articles referring to storage battery construction and practice. The galvanic battery was the first apparatus invented in the subject of electrochemistry, and the manufacture of lead storage batteries was the first great electrochemical industry. Before the introduction of the more recent electrochemical processes, in which the electric current is the means for producing chemicals, it had long been known that chemical energy is the most efficient form of energy for storing electrical energy. The storage battery has now become a necessary accessory to electric lighting and railway plants, like dynamos and other electrical apparatus.

Stationary batteries for central station work represent at present 75 per cent. of all the storage batteries manufactured. For this purpose, the position of the lead cell seems secure. In the long series of years since the lead cell was introduced into practice, many inventors have contributed to its improvement, although the cell on the whole is the same as in the days of Planté and Faure. Battery design is now being standardized. For central station work, the manufacturer no longer aims to invent a new battery, but only to increase the reliability in practice and to diminish the cost of the present lead cell.

In recent years, however, the progress of automobilism has set a new problem to the battery designer; that is, the invention of a battery of small weight and small size. The electric motor is conceded to be the ideal motor for an automobile, but the electric storage battery is far from being ideal for this purpose. The main trouble is, of course, that the lead cell is too heavy. Nevertheless, with the present batteries in the market, experience has conclusively proven that the electric automobile has a future.

Some exact data, given in this respect by Mr. Hugh Rodman in his recent American Electrochemical Society paper, are of great interest. The commercial life of lead plates in truck or cab service is about 15,000 to 20,000 miles for negatives, 12,000 miles for Planté positives and 6,000 miles for pasted positives. In other words, a 4 or 5 ton truck, running 20 miles per day for three hundred days in a year, requires new positive plates once in a year, or once in two years, according to the type of plate used. Cabs and lighter wagons have about the same life, with a capacity of 40 to 100 miles on one charge. Work done under these conditions—actual work reduced to dollars and cents—has shown that the electric wagon, as it is at present, gives better city service than can be gotten from gas or steam or horse.

Under these conditions, Mr. Rodman's conclusion is evidently justified, that if a better battery than the present lead cell was available, it would control practically all city traffic not on rails. This shows the importance of the problem. It can be solved either by devising an entirely new battery with

materials other than lead [illegible] by improving the present lead cell. Mr. Edison has adopted the first means in his celebrated [illegible] cell. His [illegible] highly interesting in several respects; that it is greatly to be regretted that authoritative statements concerning the progress of its manufacture is not available. On the other hand many skillful workers try to improve the lead cell by special means, and endeavor to adapt it to automobile practice. There is activity all around, and for this reason we trust that the descriptions of automobile batteries of American manufacturers, of which we print the first part in this issue, may be of interest to our readers. We may add that these descriptions are *ex parte* statements, based upon the information given to us from the manufacturers.

## CALCIUM CARBIDE AND ACETYLENE.

On another page of this issue we print a review of the present conditions of the calcium carbide and acetylene industries. While the commercial crisis of these industries in Continental Europe is not yet over, we are glad to note that both of these industries show signs of healthful and steady growth and progress in this country.

These industries may be considered as a typical example of the progress made by electrochemistry in conquering Nature. They represent a case of storing up the energy which is given us from Nature in waterfalls, in the form of chemical energy (calcium carbide), which may be converted afterwards into light or mechanical energy (acetylene light and motors).

Calcium carbide is universally made by water power, for the simple reason that the cost of power is a very important item in the total cost of the product, so that cheap power is essential for commercial success. Water power always existed, but was not utilized until the development of hydroelectric stations began. The electric power, generated from water-power, can conveniently be converted into light and mechanical power, and there is the great advantage that, if only a transmission line is installed, the electric power may easily be transmitted to another place and there be utilized for lighting and power. But in these transmissions and conversions of energy there is one very important thing impossible: the energy cannot be stored up.

To store up energy efficiently, it is necessary to convert it first into chemical energy. This has long been recognized by the central station engineers when they installed storage batteries, to charge them at times of light load and to discharge them at times of full load. The efficiency of this system and its economical advantages are so well recognized that this arrangement is now generally used. Now, to charge a battery when the load in the station is light means simply to store up the surplus of electrical energy in form of chemical energy, and when the battery discharges, at times of full load, this stored up energy becomes again free and available for light and power purposes. This conversion and reconversion of different forms of energy is necessarily accompanied by losses, nevertheless experience has proven beyond doubt that the total system is effective and economical.

What is done on a small scale by the storage batteries with the surplus of electrical energy in central stations is done on a much larger scale by the calcium carbide and acetylene industries with the energies of the waterfalls. The energy of the water is not the energy of the water *per se*, but that of the *falling* water; hence if it is not used or stored up just at the moment when the water falls down, the energy is lost. In hydroelectric power stations we have the means of converting the mechanical energy of the falling water into electrical energy, but, in order to store it up for future use, it is to be converted into chemical energy. This is done in the manufacture of calcium carbide in the electric furnace.

In order to make the whole process successful, it is, of course, necessary that the chemical compound which is produced in the furnace is of such a nature that the energy stored up in the same can easily be set free again and rendered available for useful purposes. This is decidedly the case with calcium carbide, as, by reaction with water, it yields acetylene. The advantages of the whole process are clearly evident. It is not astonishing that the progress of the calcium carbide industry has been rapid, but it is also evident that the progress of the calcium carbide industry must be necessarily associated with increase in the use of acetylene.

We print in this issue some remarks made by Mr. James Swinburne in his presidential address to the British Institution of Electrical Engineers on the real value of water-powers for electrometallurgical work. He thinks there is often an exaggerated value attached to water-powers, and that a water-power is useful only if it is at a place where it is wanted and needed commercially. This is exactly correct, but in his further remark, that as a rule water-power is not where it is wanted industrially, Mr. Swinburne seems to have the conditions of England merely in view. The conditions in this country are different. Niagara Falls, Massena and Sault Ste. Marie are near the great waterways and railways; transportation is cheap. These plants are commercially in touch with the commercial centers of this country. It is just for this reason that the prospects of a healthful and rapid development of electrochemical industries at those places are bright. The development of Niagara Falls as an industrial center has been an object lesson in this respect, and we trust the other great American water-power plants will equally become centers of electrochemical activity.

## FREE IONS.

When the theory of electrolytic dissociation was first put forward, it was not received with open arms by the chemical public at large; it was rather ridiculed and laughed at. In return, the promoters of this theory emphasized their standpoint with stubbornness and boldness. This explains some rather unfortunate terms used in the nomenclature of the theory. In order to emphasize that a salt when dissolved in water is in a different molecular condition than before it was dissolved, and that its two kinds of ions are in some respects independent of each other, the term dissociation was borrowed from the chemistry of gases and the term "free ions" was coined. While it was pointed out that electrolytic dissociation is essentially different from ordinary chemical dissociation, yet the old term was adopted for a new conception. The meaning of the ionic theory is now better understood, and no

serious misunderstandings may be feared at the present time from the use of the term electrolytic dissociation. Nevertheless it may be worth while to analyze briefly the ideas underlying the adoption of this term, and to show in which respects ions are "free" from the point of view of the dissociation theory.

An absolutely indisputable way of getting at the answer, and a way which excludes any misunderstanding, is to consider the differential equations, assumed by the theory of electrolytic dissociation, to govern the whole ionic mechanism. These equations, as given by Nernst (and later, in an elegant mathematical form, by Planck), are the foundation of his theories of diffusion and of concentration cells, and state exactly the sense of the theory, and there can be no dispute about their meaning.

Two different kinds of forces are assumed to exist in the interior of an electrolytic solution—osmotic forces and electrostatic forces. The osmotic forces are due to concentration differences existing in the solution. Differences of concentration at different places in the solution produce different osmotic pressures, and they tend to equalize, just as would be the case in the interior of a gas if different pressures should exist at different places, the law of the osmotic pressure and the law of the gas pressure being identical. The second kind of forces—the electrostatic forces—are due to the electrostatic charges of the ions. Each monovalent gram ion has a charge of 96,540 positive or negative coulombs, and the attractions and repulsions between the different ions are assumed to follow strictly the ordinary laws of electrostatics. If we consider any point in the interior of an electrolyte, then there is a certain force acting there, and this force is the resultant of the osmotic force and the electrostatic force existing at this point.

Now, let this total force be given at any point of the solution, and also the numbers of different kinds of ions at that point, what will happen? The theory assumes that all the positive ions will move in one direction of the line of force, and all the negative ions in the other direction. The theory further assumes that each ion tends to travel independently of the others, the speed of each ion being simply its "mobility" (Kohlrausch) multiplied by the acting force at that place. As the mobilities of the different kinds of ions are different, they would travel with different speeds, and the so far independent of each other. But nevertheless—and this is a very important point, clearly brought out in the equations of the theory—there is in any given space inside of a homogeneous solution exactly the same number of positive and of negative ions. At no space inside the solution is there free electricity.

We know there is a certain energy required for decomposing an electrolyte, say hydrochloric acid, between inert electrodes. In the sense of the theory of electrolytic dissociation, this energy corresponds to the change of the H and Cl ions into atoms. This emphasizes the fundamental difference which the theory makes between ions and atoms.

To sum up, the theory assumes a "dissociation" into ions, not atoms. The characteristic feature of each gram ion of the valency $n$ is that it is charged with $n \times 96{,}540$ coulombs. Each kind of ion has a characteristic mobility, determining the speed at which it travels under a given force. Finally, a certain energy corresponds to the change of an atom to an ion, and this energy, when measured in calories, is called the ionization heat. It is thus fairly clear that this electrolytic dissociation is essentially different from chemical dissociation.

It is therefore a pity that the promoters of this theory did not propose the concise and clear term "ionization," instead of the ambiguous term "electrolytic dissociation." Many misunderstandings would then have been avoided. Concerning the justification of the term "free ions," it all depends on what we mean by "free."

While the whole idea of the dissociation theory, when first proposed, was decidedly novel, yet the several assumptions made concerning the properties of the ions were not so. That the ions travel independently with different speeds has been known from the time of the investigations of Hittorf and Kohlrausch. Views approaching the hypothesis of dissociation had been expressed by Clausius. That each ion carries a certain charge had also been known for a long time. To quote only two authorities: "If we adopt the atomic theory or phraseology, then the atoms of bodies which are equivalent to each other in their ordinary chemical action have equal quantities of electricity naturally associated with them" (Faraday), and, "The same definite quantity of either positive or negative electricity moves always with each univalent ion, or with every unit of affinity of a multivalent ion" (Helmholtz, 1881). Nevertheless Arrhenius' famous paper was decidedly original, because he suggested distinct methods for determining the exact number of the ionized molecules and because by his theory he endeavored to save the general validity of Van't Hoff's application of the gas laws to solutions. We do not belittle his work in the least if we must admit that, in the light of more recent investigations, it becomes quite questionable whether Arrhenius' methods for determining the number of ionized molecules are really correct.

It is even quite doubtful whether the whole conception of the condition of the ionized solution is really so simple as the theory assumes. True, the theory is claimed to be strictly correct only for infinitely dilute solutions, and difficulties resulted generally from experiments with more concentrated solutions, so that they should not be used as an argument against the theory. That the theory deals with an ideal case, i. e., infinite dilution, is absolutely no reason to belittle it. It is the same thing with the theory of alternating current phenomena, which starts from the assumption of sine-curved waves which scarcely exist in practice.

Finally, we may say that some of the difficulties in the conception of ions will disappear when the more recent assumption of an ion being a compound of an atom with an electron becomes more general. Many points which are otherwise not clear are thus explained. The ionization heat is simply the formation heat of an ion from the atom and the electron. Above all, the theory becomes so simple that it recommends itself to the practical man. Every chemist uses in his calculations the conception of atoms and molecules, because they simplify the conceptions and calculations. For exactly the same reasons the "atomic theory of electricity," that is, the electron theory, recommends itself to the practical electrochemical engineer.

## WESTON INSTRUMENT PATENT DECISION.

While we are going to press we are informed that Judge Lacombe, of the United States Circuit Court of the Southern District of New York, has handed down a sweeping decision in an infringement suit instituted by the Weston Electrical Instrument Co. He sustains two Weston patents for alternating-current instruments in all points, one being a re-issue patent, dated June 28, 1892, the date of the original application being January 18, 1890, and the other, a patent subsidiary to this, dated March 8, 1892.

## JAMES SWINBURNE ON WATER-POWER AND CARBON CELLS.

Our English contemporaries just begin to reprint Mr. James Swinburne's presidential address to the (British) Institution of Electrical Engineers. The London *Electrician* editorially characterizes it as "one of the finest presidential addresses that it has been the good fortune of the Institution to listen to." To our readers Mr. Swinburne's remarks on the utilization of water power and on the prospects of carbon cells may be of special interest.

Mr. Swinburne thinks that an exaggerated value is vulgarly attached to water-powers. "As a rule water-power is not where it is wanted industrially. In the nature of things, water-powers are generally in hilly countries, and are seldom near the sea. The result is that a water-power as a rule cannot command the same price as steam or gas, because it is not where it is wanted. The idea in starting many of the water-power stations also was that works which needed power would come and settle near. As a matter of fact, the cost of power is a much smaller item in most industries than is generally supposed, and it does not pay to start a works in an otherwise not perfectly suitable locality simply for the sake of cheap water-power. . . . It may be said that in electrometallurgical processes the whole cost is practically the electrical energy, and so carbides, aluminum and electrolytic soda and chlorate of potash will be made at water-powers. Even this, however, is misleading. Carbides and aluminum are generally made at waterfalls, and chlorate nearly always is. Electrolytic soda and bleach are made at water-powers, but are also made extensively by steam-driven plants. Against the cheaper power, we have to put extra carriage for materials and for coal, which is often needed in addition; and extra carriage for finished products, and very often extra cost of labor, as labor is often dear and bad in water-power districts. Let us take, as an example, calcium carbide. The general idea is that the electrical energy is practically the whole cost of the carbide, but, taking present practice and the price of carbide at £13 10s. a ton, doubling the cost of power, instead of nearly doubling the price of the carbide, only increases it a little more than 10 per cent. Difference in local cost of coke, lime and labor, coupled with cost of carriage, may thus easily be of more importance than cheap power, even in such a case as calcium carbide, which is an electrical furnace product in which, at first sight, the power seems to be the main element of cost. In the case of electrolytic caustic and bleach, for 1 ton of caustic and the corresponding bleaching powder, the electrical energy, taken at £2 10s. per kilowatt year, a low water power cost, comes to about 17s. 6d. The caustic and bleach sell for about £20, according to a varying market. Doubling the price of power, therefore, increases the price some 5 per cent. It may thus easily pay to use much more expensive power if the other conditions are more favorable. Steam-power, for instance, will cost three or three and a half times as much, and yet it pays to make electrolytic caustic and bleach in England where the other conditions are all favorable. It is not, therefore, the want of water-power that has kept the electrolytic industry back in this country. For a water-power to be really valuable, it should be near a source of material on the sea, and should have a great head of water, so that the capital cost of development is small. Such a water-power is very valuable—to the landlord."

"A blast furnace is more valuable than a water power. There are plenty in England, but the owners, who have been wasting the gas up to now, will not give it away; they will want rent, so that it will only just pay to use his gas rather than make it. The electrical industry thus does not gain, but the iron masters do."

Mr. Swinburne's remarks on carbon cells are as follows:

"For many years 'electrical energy direct from coal' has been the dream of the electrochemist. That is to say, he has dreamed of an electrolytic cell in which the consumed electrode is carbon. The best way to realize the difficulties of this problem is to consider it solved and see what it means. The carbon must be in contact with an electrolyte, and the electrolyte must either be in contact with a second electrolyte, which wets the other electrode, or must itself be in contact with that electrode. This second electrode must almost certainly be metal, as there are no other non-metallic conductors available. The electrolyte in contact with the carbon must be a salt of carbon or must contain a salt of carbon, or it must contain another salt whose positive radicle can be replaced by carbon. Such compounds as the hydrides, nitride, oxides, chloride, bromide or the sulphide or silicide of carbon are not salts in the electrolytic sense. Carbon forms part of the electropositive radicle in the organic radicles, and part of the electronegative radicle in the cyanogen compounds, but it is never a radicle by itself. To sum up the matter shortly in the light of modern theory, carbon never forms ions, and has, therefore, no solution pressure, and can, therefore, give no e. m. f. At ordinary or moderate temperatures carbon is practically inert. Oxidizing agents will attack some forms lightly, and sulphuric acid will attack it. In this latter case the formation of water and its combination with the acid is the determining factor. At high temperatures, oxygen, sulphur, silicon, and to some extent nitrogen and many of the metals, combine with carbon, but there is no dissociable salt of carbon formed. The carbon cell thus seems impossible. Such schemes as Mr. Reed's, ingenious as it is, is not a solution of the problem. It would be simpler to reduce zinc oxide with the carbon, and then put it in a zinc cell. It is hardly necessary to discuss thermopiles or thermo-magnetic engines as possible economical producers of electric power."

## OVERVOLTAGE.

In the recently-issued second volume of the "Transactions of the American Electrochemical Society," page 83, some of the remarks made by Dr. F. Haber, in the discussion of Mr. Weightman's paper, appear somewhat ambiguous, as Dr. Haber had no opportunity to revise the stenographer's report. As the matter is of some interest, we give herewith the substance of a letter recently addressed by him to the president of the Society.

Dr. Haber intended to say in those remarks that overvoltage, which is a newly-coined word for an old, well known phenomenon, refers to the fact that it requires a higher voltage to develop gases on certain electrodes than would be expected from the thermodynamic theory. From his point of view, it means that the gaseous compound is not formed from the ions at one single step, but that an intermediate product is first formed, as, for instance, in the case of hydrogen it may be an alloy of that gas and the metal of the cathode, or a solution or occlusion of hydrogen in or at the metal of the cathode. He emphasized the idea, that the properties of this intermediate product were responsible for the phenomenon, although he had to admit that we are not yet quite able to make such a definite statement of this property as will cover the ground perfectly. He gave as an example the behavior of mercury as cathode in dilute sulphuric acid to explain this subject.

## SODIUM CHLORID IN ELECTROLYTIC CAUSTIC ALKALI.

By Clinton Paul Townsend.

In a former paper (Electrochemical Industry, Vol. I, page 23) the writer discussed in a general way the influence of the movement of the products of electrolysis upon the course of the reaction in the electrolysis of sodium chlorid solutions, and referred to the several types of cell which have been proposed or used, considering these types particularly from the point of view of the means employed for checking such movement between the respective compartments of the cell.

In every electrolytic cell capable of producing caustic soda such means are present; in their absence, the cell passes into the type adapted for the production of bleach liquor or chlorate. The idea of means differs, of course, very widely, and may comprise a stationary septum of mercury entirely impervious to a liquid; a moving body of mercury; a diaphragm, one side of which may be unsubmerged in order to allow the product to flow freely from it; a definite direction and rate of liquid flow, or merely such disposition of parts as will avoid or minimize agitation by escaping gases, convection currents or the feed and discharge of the electrolyte.

The purpose of the present paper is to consider a single aspect of this question, viz.: the movement of undecomposed sodium chlorid into the caustic compartment.

Sodium chlorid is soluble in caustic soda solutions to a degree dependent on the concentration of the hydroxid. A solution containing 10 grams of caustic soda per litre is capable of dissolving 308 grams of sodium chlorid, while a solution containing 640 grams of caustic per litre can dissolve only 18 grams of salt. The solubilities of salt in caustic of various concentrations at 20° C. have been accurately determined by F. Winteler (*Zeitschrift fur Elektrochemie*, 7, page 360).

Of the several general types of cell mentioned above, one only is capable of yielding a caustic solution absolutely free from dissolved chlorid. This is the cell, as originally suggested by Vautin and modified by Kellner, and later by Edser, wherein the caustic compartment is separated from the remainder of the cell by a stationary septum (cathode) of mercury, which is pervious to metallic sodium, but not to water or compounds in solution therein. The term "stationary" is here employed to indicate that the mercury is not transferred bodily from one point to another during the operation. An internal movement of the mercury, to aid the slow process of diffusion in transferring the metal from the surface of deposition to that of oxidation, is, of course, essential, since otherwise both the capacity and the efficiency of the arrangement would be very low. The provision of means which should entail neither undue complication of parts nor too great expenditure of energy for producing a sufficiently rapid transfer of the dissolved alkali metal would make this cell the ideal one for the production of pure caustic solutions.

If the body of mercury be moved continuously or intermittently between decomposing and oxidizing compartments beneath a depending partial partition, the mercury itself constituting a seal between the respective solutions, the quantity of chloride which will be transferred from the electrolyzing compartment to the caustic side and the quantity of caustic transferred in the reverse direction depend largely upon the exposed surface of the mercury and the velocity imparted to it. It is essentially a transfer by wet surfaces, and is not considered to affect seriously the commercial operation of the cell. It is a phenomenon entirely different from that to be considered here.

Let us consider next a construction comprising two electrodes of opposite polarity, an outflow opening adjacent to each and a single inlet for the electrolyte, such inlet being situated between the electrodes and serving to produce a flow of the electrolyte in opposite directions from the intermediate part. It will be clear that if the rate of flow of the electrolyte be sufficient to overcome the backward diffusion of the reaction products and their movement caused by other agencies, the cathode liquor will consist only of the hydroxid and chlorid of sodium. If the current efficiency reaches 100 per cent., which can be measurably attained under these conditions with sufficiently rapid flow, the composition of the liquid flowing past the cathode can be readily calculated. A quantity of the sodium chlorid equivalent to the current used has yielded caustic according to the equation

$$NaCl + nH_2O = Cl + H + NaOH + (n-1)H_2O;$$

the proportions of chlorid and hydrate being molecular, but a concentrating effect due to the decomposition of water supervening. The exact composition corresponding to any given current and liquid flow and composition of electrolyte is, of course, readily determined.

The above construction fairly represents in principle the type of "gravity cells." If the flow of the liquid be rapid, assuming that the maximum permissible current density is employed, the current efficiency will be high, but the cathode lye will be low in caustic and high in salt. For the withdrawal of the products and the prevention of secondary reactions, a certain minimum rate of flow is essential, and this rate of flow is, in the cell constructions as yet proposed, too high to admit of thoroughly satisfactory concentrations of caustic.

The ratio which the quantity of salt electrolyzed bears to the total quantity passing the cathode is the decomposition efficiency. There is, at moderate rates of flow, in a cell of the type above referred to, an inverse relationship between decomposition efficiency and current efficiency; and a perfect decomposition efficiency, at even moderate current efficiency, will always be impossible in the absence of means for removing the cathode products from the field of electrolytic decomposition absolutely at the instant of their formation.

The above considerations will make clear the true function and character of the diaphragm in a caustic cell. It is essentially a device for controlling and equalizing the forward movement of the electrolyte and for retarding the backward movement of the products of electrolysis, and thereby permitting the establishment of a new and lower minimum flow for their removal. It is in no sense to be considered as a septum capable of permitting the passage of the electric current, but of preventing the diffusion and recombination of the products in stationary bodies of electrolyte. Yet this latter conception seems to be the common one among workers in the art. The new minimum thus established corresponds to higher concentrations of caustic with equal current efficiencies.

A solution of sodium chlorid saturated at ordinary temperatures corresponds approximately to the formula $NaCl + 9H_2O$. Complete decomposition proceeds according to the equation

$$NaCl + 9H_2O = Cl + H + NaOH + 8H_2O,$$

the per cent. of caustic in the resulting lye being theoretically 21.7. It would appear, therefore, that this figure should be regarded as the maximum concentration of caustic obtainable by direct reaction from any electrolytic cell which depends upon the water of the electrolyte for oxidation of the metal sodium. It is interesting, therefore, to observe that this concentration is easily exceeded; that no sharp break in current efficiency occurs at or near this figure, and that cathode lyes of the approximate caustic content above noted have been found to contain a quantity of undecomposed salt which corresponds nearly to their saturation point.

The cell from which the following curves were obtained need not be further described than by the statement that it was provided with a thin permeable diaphragm, adapted to restrain and equalize the flow of the electrolyte and a cathode whose form fitted it to serve as a surface for the rapid discharge of the cathode products. The annexed diagram (Fig. 1) shows in solid lines (A) the percentages of caustic and (B) the percentages of undecomposed salt. The broken curve (C) indicates the saturation curve of salt corresponding to the caustic

found. The analyses from which the curves were plotted were made at forty-minute intervals.

It will be noted of these curves that the caustic attains approximately the supposed theoretical maximum above referred to, and that the undecomposed salt is present nearly to saturation of the caustic. It will be further noted that there is apparently a strong concentration effect, inasmuch as the sum of the salt found, and the salt equivalent of the caustic, is far in excess of the saturation point for aqueous solutions of

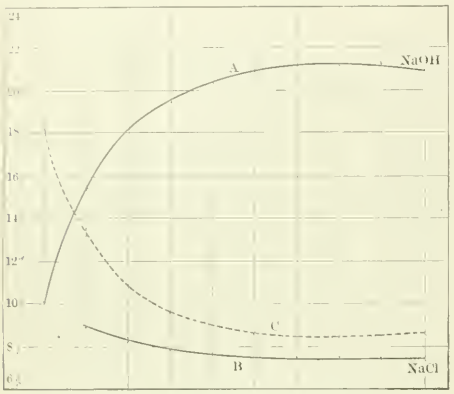



FIG. 1.—SODIUM CHLORID ELETROLYSIS.

salt. This is, without doubt, due in part to concentration of the cathode liquor by loss of water with the escaping hydrogen, in part to the cathodic reduction of hypochlorite and in part to the movement of the salt through the diaphragm under the influence of the difference of osmotic pressure upon opposite sides of the membrane.

These results suggest at once a query as to the relative proportions of caustic and salt in the cathode product of the electrolysis of more dilute sodium chloride solutions. A solu-

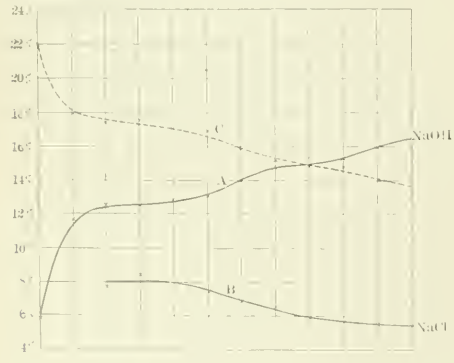



FIG. 2.—SODIUM CHLORID ELECTROLYSIS.

tion corresponding approximately to the formula $NaCl + 15H_2O$ was electrolyzed. The theoretical concentration of caustic obtainable from such solution, if completely electrolyzed without concentration, is 13.7. The results are shown in Fig. 2, curves A, B and C representing, as before, percentages of NaOH, NaCl and the saturation curve of salt in caustic respectively.

The irregular form of the caustic curve in this case, indicating as it does an intermittent progress to concentrations considerably exceeding those theoretically attainable without loss of water, is not easily explained, inasmuch as the electrolyzing current was maintained substantially constant, and the rate of flow of the solution underwent no corresponding variations, but diminished slowly and regularly from the beginning to the end of the experiment, which occupied 440 minutes. The analyses in this, as in the other cases, were made at intervals of forty minutes. The broken curve C, representing as it does merely the percentages of salt required to saturate the caustic of the curve A, is substantially the reverse of the latter. Most peculiar, however, is the close parallelism between the curve B, representing the saturation line, and the curve C, representing actual salt content. The latter parallels the former, the interval between them corresponding to about 9 per cent. of salt.

The electrolyte was then diluted to the composition $NaCl + 18H_2O$ and the curve secured, as shown in Fig. 3. This solu-

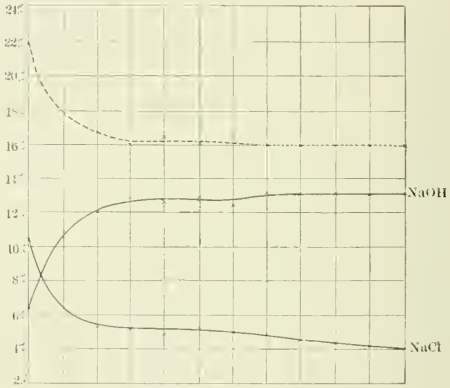



FIG. 3.—SODIUM CHLORID ELECTROLYSIS.

tion, completely converted into caustic without further concentration than is called for by the reaction, should yield a liquid containing 11.6 per cent. NaOH. As in the previous case, the concentration obtained is considerably in excess of this figure. The salt curve B again nearly parallels the saturation line C, but the interval between them is now approximately 11.5 per cent.

These results clearly show the controlling influences of the concentration of the electrolyte upon the salt content of the resulting caustic. In a subsequent note the writer hopes to discuss the character and limits of this relationship.

The history of the development of the diaphragm type of caustic cells is one of the most interesting chapters of electrochemistry, but it is largely a story of individual failure. It is usual to regard the defects of high resistance, low concentration and purity of product and rapid deterioration in use as inherent in cells operating by this method, but the whole tendency of recent work is to the effect that such is not necessarily the case. A diaphragm adapted to perform its true and proper function need neither offer high electrical resistance nor be perishable; it is only when the work of maintaining a separation of the products of electrolysis—a result which should be secured by other means—is imposed upon the diaphragm that it becomes an inefficient tool and a troublesome element of the cell.

INTERNATIONAL CONGRESS FOR APPLIED CHEMISTRY.—The arrangements for the meetings of the electrochemical section of this congress, to be held in Berlin next year, are in charge of the German Bunsen Society. Besides the papers to be read, it is intended to have experts present reports on the following subjects: The scientific and technical problems of the chemistry of calcium carbide; electrochemical methods for preparing organic compounds; the problems of physical chemistry in the manufacture of sulphuric acid; fixation of atmospheric nitrogen.

## PIONEERS OF ELECTROCHEMISTRY—IV.

### HAMILTON YOUNG CASTNER.

Although the subject of this sketch is no longer among the living, yet it is none the less highly appropriate that his name should be placed here among the pioneers of electrochemistry.

Born in Brooklyn, N. Y., on September 11, 1859, educated at a private school, and entering Columbia College School of Mines as a student in chemistry in 1875, Mr. Castner had the great good fortune to come into personal contact during three industrious years with Dr. Chas. F. Chandler, and the warm friendship between teacher and student continued all through his subsequent career. In fact, as a last tribute to its successful student, the School of Mines is about to place in the corridor of its new home, on Morningside Heights, Havermeyer Hall, a bronze tablet commemorative of his name and achievements.

Leaving college in 1878, Mr. Castner established himself as an analytical chemist, and in his spare time was constantly experimenting with chemical and metallurgical processes. He invented an improvement in the manufacture of bone black. Later he became enthusiastic over the possibilty of cheapening the cost of aluminum, which, in 1880, was selling at $12 per pound, and he directed his experiments towards finding a cheaper method of producing sodium. His laboratory, on West Twentieth street, three floors high, was filled with furnaces and apparatus, and out of it emerged, in 1886, a successful process for producing sodium by reducing caustic soda by a mixture of iron and carbon, in steel pots, in a regenerative gas furnace. Instead of costing $2 per pound, sodium was thus obtained for about 20 cents per pound, and the way to cheaper aluminum was open. Each pound of aluminum requiring 3 pounds of sodium to reduce it, the saving on the former was easily $5 per pound. The United States patent for this process is 342,897, of June 1, 1886.

H. Y. Castner

Going over to England, Mr Castner put up an experimental furnace in London, and, on proving his claims to the satisfaction of Sir Henry Roscoe and other chemical experts, the Aluminum Co., Ltd., was formed, and the erection of large works commenced at Oldbury, near Birmingham. (This town is the writer's birthplace, and it was at this time that the writer's personal acquaintance with Mr. Castner began, an acquaintance which, during twelve years, ripened into sincere friendship.)

In connection with this enterprise, Mr. Castner patented improvements in the manufacture of aluminum chloride and the furnaces used in reduction. The plant was extensive and well planned. Mr. Brindley, now manager of the sodium manufacture at Niagara Falls, was his chief of construction. In 1888 this plant was making 1,500 pounds of sodium per day, and therewith 500 pounds of aluminium, which was sold at $5 per pound. But dark days were ahead. The electrolytic processes for making aluminum were being perfected, and the very next year the competition was felt. Prices went down and down, until at last, in 1891, when it sold for 85 cents per pound, the chemical process was forced to acknowledge itself out of the race, although the sodium it used was costing only 10 cents per pound.

At this point Mr. Castner showed his mettle, and actually, by main force of his wonderful energy, saved his company from bankruptcy. With $250,000 invested in a plant which was practically useless and a capital of $500,000 at stake, he turned to find new uses for metallic sodium, and practically created the present sodium industry. He found a method of making sodium peroixde for bleaching purposes; he invented a process for making sodium cyanide from crude ferrocyanide, he exploited the use of sodium in making organic chemicals, such as antipyrin, and the manufacture of chemically pure caustic soda from the metal. With these opportunities for business, his company continued in existence as "The Aluminum Co., Ltd.," but made not a pound of aluminum, making profits on sodium alone.

At this period Mr. Castner became an electrochemist. Driven out of the aluminum business by electrolytic methods, he was quick to perceive the advantages of such processes, and he commenced experimenting on the electrolysis of fused caustic soda. Bringing to this his skill as an analytical chemist, with his experience in chemical engineering, the way was open to him for great achievements. His United States patent of May 12, 1891, describes the electrolytic process practically as it is carried on to-day, and established his pre-eminence in the sodium business more firmly than ever. The need for pure caustic soda, to use in manufacturing sodium, set him to experimenting in the electrolysis of sodium chloride, and by 1894 we had his perfected apparatus and process for the use of a movable mercury floor to a double cell the most elegant electrolytic process ever invented. (U. S. patents, Apr l 10th and October 30, 1894.) It is unnecessary here to describe that well known process. The writer saw the 200 horse-power experimental plant at Oldbury, which has since expanded into the 4,000 horse-power plant at Runcorn Point, on the Mersey, and the magnificent 6,000 horse-power plant at Niagara Falls. And we must not omit to record the integrity of the inventor, who turned his invention over to his once financially ruined company and brought them into such a position that they have made more profit from the soda and sodium business than they had ever hoped to make from the aluminum business. Such a turning of defeat into victory is seldom recorded in industrial annals, and the continued existence of his company is one of the finest monuments to the industry, skill and integrity of Mr Castner. In connection with this business, numerous patents on details of apparatus, baking of carbons, purification of the brine, etc., attest the ever active inventive genius.

It is not, however, alone as an inventor that we wish to speak of Mr Castner's abilities. He possessed the rare combination of high inventive ability, the genius of putting inventions into commercial, working form and good business instincts. He could not only devise, but he could construct, work and manage, and by his attractive personality he could win and hold friends and make his business position secure.

A disposition towards consumption made his health always precarious. The English winter drove him into exile to Florida or the Riviera. In October, 1899, he died at Saranac Lake, N. Y., at the untimely age of forty. His death has been a great loss to the art of electrochemistry, but his life-work will continue to be one of the brightest examples of how to win and to hold success that appears in the annals of that science.

## A NOTE ON THE CONDUCTIVITY OF NICKEL OXIDES

By A. L. Marsh.

[illegible] be the prevailing opinion that nickel peroxide is a conductor of electricity, and that, to render this material [illegible] in the storage battery, it must be mixed with a sufficient quantity of inert conducting material, such as flake graphite, to make the mass a conductor. Mr. Edison uses such a mixture in his new nickel-iron cell. While I have made no direct measurements of the conductivity of the oxides of nickel, it seems to me that the two experiments described below indicate that this compound cannot be classed as a non-conductor.

Hydrated nickel peroxide deposits as a rather dense, black coating on the anode when an alkaline tartrate solution of nickel is electrolyzed. This deposit does not noticeably reduce the current or prevent further deposition of peroxide on its surface. Electrodeposited conducting bodies may be built up one layer upon another, while non-conducting bodies act as porous partitions or diaphragms, through which further action takes place, and each succeeding layer of the material is set free at the surface of the metal electrode, assuming that the metal electrode is unattacked in each case.

In another experiment a cell was constructed having a layer of black oxide of nickel ($Ni_2O_3$) more than three sixteenths of an inch in thickness, surrounding a strip of nickel gauze. This oxide, which was partially hydrated, formed the active material of the positive electrode. Spongy cadmium, surrounding a strip of sheet iron, formed the negative electrode. There was no inert conducting substance mixed with the nickel oxide, yet the cell showed a very fair capacity per total weight.

I believe that electrochemically active nickel peroxide is a hydrated compound, and that the one with the proper degree of hydration is a fairly good conductor of electricity compared with lead peroxide.

But little is known of nickel peroxide. The lower oxides have, however, been better studied, and these are the ones used in the battery and from which the peroxide is formed electrochemically.

Nickel sesquioxide may be obtained in at least three different conditions, namely, anhydrous, $Ni_2O_3$; partially hydrated, $Ni_2O_3 \cdot 2H_2O$, and hydroxide, $Ni_2(OH)_6$. The second, $Ni_2O_3 \cdot 3H_2O$, is the compound which Wernicke believed to be formed during the electrolysis of an alkaline tartrate solution of nickel, but I think it more likely that nickel peroxide is at first formed and becomes reduced by a secondary action, due to the reducing medium in which it is formed.

There may be an analogy between the sesquioxide of nickel and lead peroxide as regards their conductivity with different degrees of hydration. Anhydrous lead peroxide is a very poor conductor compared with the hydrated peroxide formed at the anode during the electrolysis of a nitric acid solution of lead nitrate, so we might expect to find anhydrous nickel sequioxide a poor conductor compared with the hydrated varieties of the same compound.

Nickel sesquioxide, prepared by heating nickel nitrate, $Ni(NO_3)_2$, is anhydrous, and when this compound was used to form the peroxide electrolytically very poor results were obtained. Poor results were also obtained when the green oxide of nickel was used in the same way. In both of these cases the oxides used were not in the proper condition for rapid and efficient formation into the hydrated nickel peroxide, which I assume to be the compound of nickel of the charged electrode. In these cases an admixture of graphite might have aided the formation. Heat seems to render the oxides of nickel inert, as it does the oxides of the similar metal iron. Lead peroxides can be formed electrolytically from the lower oxide, PbO, prepared by heat, and therefore anhydrous. Heat does not affect the oxide of lead as it does the oxide of iron, for the oxide of lead is readily dissolved by nitric acid, while the oxide of iron becomes practically insoluble after being heated. Nickel being a metal somewhat similar to iron, we should expect its oxide to become less active after being heated, and this seems to be the case in regard to its behavior towards electrolytic oxidation.

Nickel hydroxide is a very bulky compound, and practically the same objections to its use in the storage battery are found as Mr. Edison has found in the use of the bulky hydroxide of iron for the negative electrode of his cell.

In my experience, the best compound of nickel to use in the storage cell is the hydrated sesquioxide, $Ni_2O_3 \cdot (H_2O)_x$, in which x represents a quantity of water less than the hydroxide contains. This compound can be peroxidized electrolytically with ease, and without the aid of inert conducting substances. In preparing this hydrated sesquioxide, I use the following method:

Nickel sulphate is dissolved in water, and by adding a strong solution of caustic soda, green nickelous hydroxide is precipitated. An excess of the caustic soda solution is added, and then a current of chlorine gas is allowed slowly to bubble through the liquid containing the nickelous hydroxide in suspension until that compound becomes jet black and all of it has been oxydized to nickelic hydroxide, $Ni_2(OH)_6$. The black hydroxide is then washed free from alkali and salts, and then spread out in the air to dry. A large shrinkage occurs in the mass, due perhaps to the loss of a part of the water of hydration. The air-dried material is ready for use in the battery.

While I do not think the flake graphite necessary to increase the conductivity of the active mass, especially when the compound is properly prepared, yet I do think that it may perform a valuable service in the positive electrode by preventing the peroxide from falling out of a perforated grid. My experience with the peroxide of nickel has shown that there is but little cohesion between the particles of oxide, even after the mass has been subjected to a considerable pressure. The particles very readily pass through the small openings of the grid, and to prevent this the flake graphite may be of some value.

From the evidence stated above, I think that nickel peroxide should not be termed a non-conductor, even from a practical standpoint, but should be classed with the conductors.

## HOW TO DETERMINE THE BEST CONDITIONS IN STORAGE-BATTERY PRACTICE.

By Carl Hering.

In expressing opinions on a storage battery, there are two extremes to which those judging them are likely to go. On the one hand the so-called scientist or theorist, who too often has an unwarranted contempt for matters involving dollars and cents, is apt to lay great stress on such qualities as the efficiency, the internal resistance, the voltage, drop in voltage, etc., ignoring completely the purely commercial considerations.

On the other hand the so-called practical or "self-made" man, who has often not had a proper training in the principles and laws involved, and too often has an unwarranted contempt for what he calls mere theories, generally meaning thereby a good scientific education and ability to make calculations, will be apt to fail to notice serious and often fatal defects in a battery, which, though perhaps not evident at first, are certain to develop later.

When any piece of scientific apparatus, as the original storage battery was, is to be used industrially, it is just as important to consider the questions of dollars and cents as the purely scientific features. The proper way to judge a battery as a commercial article is to give proper weight to both.

Dynamos and motors might, perhaps, be built with as high an efficiency as 99 per cent., but every well-trained electrical engineer knows that they would then become so expensive that no one would buy them. They would be a scientific success,

but a commercial failure. On the other hand, very cheap ones could be built of very low efficiency, but a person who can calculate in advance will often find that this continual loss of power will in the course of time amount to more in cost than the original difference in price. There is always a proper mean between these two extremes, and it is the duty of the trained engineer to determine this.

As this is well understood among those who make, sell or buy dynamos and motors, it is strange to see that the same reasoning is not more generally applied to storage batteries. One reason, undoubtedly, is that the corresponding calculations are not quite so simple, and the required data are not always at hand. But this does not excuse ignoring these questions completely.

A very similar case is found in the determination of the most economical use of incandescent lamps, which is also somewhat complicated, and although the author called attention to a method nearly ten years ago, and showed* how the conditions of the lowest cost in their use may be determined, it was not until recently that the principles involved were begun to be recognized.

As the conditions are in some respects somewhat similar in determining the most economical use and construction of incandescent lamps, and the most economical use and construction of storage batteries, and as the former method may not yet be generally understood, it may be briefly described here to facilitate the understanding of the latter.

A lamp may be made to have a long life, and the cost of the lamp itself per hour of its life will therefore be small. The efficiency, however, will then be poor and the cost of the current per candle power hour will be relatively high. On the other hand the lamp may be made to have a high efficiency, but a short life, and the cost of the lamp per hour then becomes greater, while that of the current becomes less. The gradual deterioration by blackening of the globe and the reduction in efficiency may be included in the above by using a candle power hour as the unit instead of the lamp hour.

Now the total cost to the user is, of course, the sum of these two; it is evidently immaterial to him how this cost is divided between the two, as he is only concerned with the total. This total cost will rise by going to either of these extremes, hence there must be a minimum cost somewhere between the two, and the question is to find the conditions under which this minimum is reached. This minimum, of course, will be different for different costs of the lamps, and for different costs of the power, but the method of determining it is the same for all.

The way to do this is to plot two curves, one of which shows for each successive hour in the life of a lamp, the total quantity of light given off by it in candle power hours, from the time the new lamp was first started. The other curve gives for each successive hour in the life of the lamp, the total cost of this light; that is, the original cost of the lamp added to the cost of all the energy consumed by it from the time the new lamp was first started, up to the respective hour. If for each hour this total cost, at that hour, as given in the second curve, be divided by the total quantity of light delivered up to that hour, as given by the first curve, the quotient will be the average cost per candle hour from the start to that hour. When these quotients are plotted as a third curve it will be found to have a minimum point; that is, a point where this average cost will be the smallest. It will be cheapest to discard the lamp at that hour of its life even though it may not be broken or greatly blackened.

The general method of finding such a minimum is as follows. First of all, there is the specific quantity under discussion, whose minimum (or perhaps maximum) is to be found; it was the average cost of the light per candle hour in the above case; in accumulators it might be cost of the battery per kilowatt hour capacity per discharge, or the length of run of an automobile driven by it (in which case it is the maximum that is sought), or the cost of the battery per mile run of an automobile before the battery must be renewed, or the number of miles run per dollar of cost of battery, or the cost of a kilowatt hour of the energy delivered, etc.; with batteries there are a number of such quantities. This quantity is usually made the ordinate, that is, the vertical scale of the final curve; it will, of course, always be different from either of the vertical scales of the two original curves, as will appear later.

The next step is to be reasonably sure that a minimum (or maximum) value can be expected. For instance, the first cost of a lead battery per kilowatt hour capacity will (in general) go on increasing indefinitely when the weight is increased and will never have a minimum, its least value will be when the weight is nothing, which in practice simply means the lighter the cheaper. The general rule to find in advance whether there is likely to be a minimum is to see whether the quantity under consideration will *increase* when one goes to both of two opposite extremes, if so, there must be a minimum somewhere between them. For instance, if one continues to decrease the weight of a battery, its life will be shortened and the cost of renewing the battery will increase the total cost per kilowatt hour capacity; on the other hand, to make it extremely heavy will increase the life, but again increase the total cost as the original cost will then be high; there is, therefore, a minimum somewhere between these two extremes.

The next step is to select the other ordinate of the curve; that is, the quantity or units in terms of which the time or condition of the occurrence of this minimum is expressed. In other words, it is some convenient quantity or scale which shows *when* this minimum is reached, while the other one shows *what* or *how much* this minimum is. In the case of the lamp it was the time in hours, and it showed at what hour the cost was a minimum. There may often be some latitude in the selection of this quantity as it enters into the question only as a sort of a scale to show when the minimum is reached. With storage batteries it might be the weight, the life, the number of cells, etc. The only conditions in its selection are that it must not, of course, be the quantity whose minimum is to be determined, and it must be the same for all the three curves, that is, for the two original curves and for the final curve. For the latter reason its selection will be governed largely by the data at hand, or which can be acquired. This quantity is usually made the abscissa, that is, the horizontal scale of the curve.

Having thus selected the two final scales to be used, the next step is to plot from known data the two (or perhaps more) original curves from which the final one is to be determined either by the addition, subtraction, multiplication or division of the two (or more) corresponding ordinates. This is shown best by the examples which follow.

The last step is to calculate and plot the final and desired curve from the two (or more) given original curves of data, the nature of the calculation, of course, depending upon what quantities the original and final curves express. This is best done roughly at first to find if there really is a minimum point and approximately where it is, as it may be beyond the practical limits of construction or use; after locating it approximately, calculate more accurately numerous points in the vicinity of the minimum point and draw the curve through them. The minimum value is then read off on the vertical scale, and the condition when this minimum is reached is read off on the horizontal scale. All that was said about the minimum point applies, of course, equally well to a maximum point.

Minimum and maximum points can also, of course, be readily calculated algebraically by means of the differential calculus, but this requires that the original data be given in the form of algebraic equations, and in many cases, especially

* Transactions of the American Institute of Electrical Engineers, vol 10, 1893, p. 65.

...ver the original data are all obtained from experiments and ...ften fairly accurate and often somewhat hazardous to ...determine from curves, the amount of work being often ...greater than the accuracy of the curves. Moreover, such equations are generally only approximate, and the errors thereby involved may change the location or amount of the minimum point quite appreciably. Another advantage of the graphical method with the curves, is that it is much easier to understand and safer to use, for those who are not very familiar with the differential calculus.

To illustrate the application of the above described general method of curves for determining the best conditions in storage battery practice, a few specific examples are here given in the following figures. It is to be noted, however, that the curves given are intended only to illustrate the method, and not to give actual values, for in some cases they have been exaggerated or distorted to serve their purpose better as examples of the method; moreover the original data may sometimes be so different from those indicated that there may not be a minimum at all, or it may lie beyond practical limits.

The numerical values of the divisions of the scales have been purposely omitted; the horizontal ones must, of course, be the same in all three curves of each example, and the vertical ones are generally very different in amount and always different in the thing they represent.

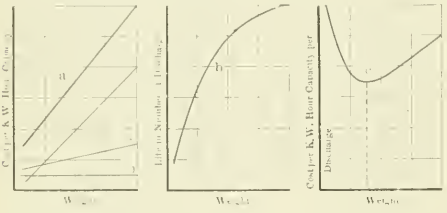



FIG. 1.—COST OF BATTERY AS FUNCTION OF WEIGHT.

The three curves of Fig. 1, show how to determine for what weight of cell the cost of the battery itself (not including the cost of the power) will be least per kilowatt hour capacity per discharge. The first two curves *a* and *b* give the original data, and the third one *c* gives the final result. The horizontal scales in all three are the weights, as that is the quantity to be used to indicate *when* the minimum point is reached. It might have been made the number of cells or perhaps some other quantity according to what one wants to take as the variable measure.

Curve *a* gives the different costs of a battery per kilowatt hour capacity when made of different weights of plates. It is made up of curve 1, which may represent the cost of forming or pasting, and will be the same for all weights, as the amount of active material is the same in all, because the capacity is assumed to be the same. Curve 2 is the cost of the jar and fixtures, which increases only slightly as the plates become thicker. Curve 3 is the cost of the lead, which increases in direct proportion to the weight. Curve 4 is the sum of these three and is the total cost, which is to be used in determining curve *c*, the subsidiary curves 1, 2 and 3 being merely given here to show how the curve *c* is itself determined.

Curve *b* gives the life in number of discharges for increasing weights; for extremely thin, light plates the number of discharges is small, it then increases as the plates are made thicker, but not as fast as the weight.

Curve *c* is the final curve desired. It is obtained by dividing, for each weight, the vertical distances or ordinates of curve *a* by the corresponding ones of curve *b*. This gives the cost per kilowatt hour of battery per discharge, and it will be seen to have a minimum value at a certain weight.

Fig. 2 shows how to determine for what weight of battery the length of the total run is greatest, for an automobile driven by it. This is a case of a maximum value. Having given an automobile of definite weight, a very light battery will run it a great distance per discharge, as there will be less dead weight of battery to carry, but the battery will have a short life, that is, it will not stand a great number of discharges, hence the total distance before the battery must be replaced, will become less. On the other hand to make it very heavy will increase the life in number of discharges, but there will be such a heavy weight to carry that the length of run for each discharge will be small. There is, therefore, probably a

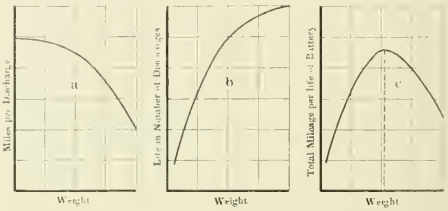



FIG. 2.—WEIGHT OF AUTOMOBILE BATTERIES.

certain weight at which there is a maximum value of the total mileage before the battery must be renewed.

The horizontal scale in all these three curves of Fig. 2, is the weight, as we want to know at what weight of battery this maximum occurs.

The first curve *a* gives the miles run per discharge, for batteries of different weights; this is great for a light battery and becomes less as the weight is increased. Curve *b* gives the life in number of discharges before the battery must be replaced by a new one; this is small for a light, short-lived battery, and becomes longer as the battery is made heavier. Multiplying each ordinate or vertical distance of curve *a* by the corresponding one of curve *b*, evidently gives the total length of all the runs that a battery will stand before it will give out. This gives curve *c*, which is the one desired and which shows that for a certain weight the total distance becomes greatest.

Had the horizontal scales been made cost, the result would have shown at what cost of battery this total run would be greatest.

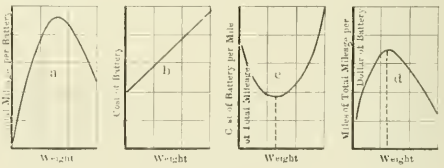



FIG. 3.—COST OF AUTOMOBILE BATTERIES AS FUNCTION OF WEIGHT.

The first three curves of Fig. 3 show how to determine at what weight of an automobile battery, the cost of the battery per mile of its total life, is a minimum. Curve *a* shows the total mileage per battery during its life; it is the same as the final curve *c* of the example in Fig. 2, thus showing how one can go from one curve to others, as in the present example this curve is used as original data. The second curve *b*, gives the cost of the battery when made of different weights. The third curve *c* is obtained by dividing the ordinates of the second curve *b*, by those of the first *a*, and it therefore shows at what weight of battery the cost of the battery is least per mile of its whole life, which are the conditions sought.

Instead of obtaining the minimum curve *c* by dividing *b* by *a*, a maximum curve may be obtained by dividing *a* by *b*; this is shown in curve *d*, which then shows at what weight the total mileage is greatest for the whole life of a battery and per dollar cost of the battery. Curve *d* is evidently only the recip-

rocal of curve *c*, and it is a mere matter of choice between them, as the ultimate result is the same in both.

The three curves of Fig. 4 show how to find at what age in its life is the average cost of one kilowatt hour of energy given out by it, a minimum. It takes into account the gradual depreciation of the capacity of the battery, and it differs from the other examples in that the curves are what are called integration curves; that is, the vertical distances represent totals, or the summing up of all the previous costs or amounts of energy up to that point, and therefore one can, from such values, find what the *average* value has been up to any particular age of its life. This case is quite similar to the one above described concerning the best age of incandescent lamps.

FIG. 4.—AVERAGE COST OF ENERGY OF A BATTERY.

It is here assumed that as the battery gradually depreciates, the amount of energy given out by it per discharge becomes less and less, although the amount put into it is the same. During the first part of its life the average of the total cost of both energy and battery will be great, because the first cost of the battery itself distributed over comparatively few discharges will be relatively great. On the other hand, if the battery is used for very many discharges its first cost per total kilowatt hours delivered will become very small, because the total number of kilowatt hours delivered by it during the many repeated discharges is very great. But owing to the depreciation of the capacity, the cost of the power delivered by it becomes greater because the capacity is reduced, although the power for charging it remains the same; therefore the average of the total cost of a kilowatt hour of energy delivered, including both the cost of power and battery, will be least at some age between these two extremes.

The horizontal scales in all of them represent the age or life stated in number of discharges. Curve *a* gives the *total* costs paid out up to the end of each discharge; it is made up of several subsidiary curves 1, 2 and 3. Curve 1 is the original cost of the battery, which, having once been paid, is therefore the same for every ordinate. Curve 2 represents the depreciation in the cost of the battery; it is here shown as based on a certain sum of money which must be charged or laid aside at every discharge, so that at the end of the life of the battery it equals the amount necessary to renew the worn out parts; but as has already been described it is a summation curve, each value of which is the *total sum* which has thus been laid aside from the beginning up to that particular discharge. This curve 2 is moreover drawn above curve 1, instead of beginning at the origin as it should if it were by itself, as the ordinate of the two curves are hereby added, and the ordinates of curve 2, in the way it is drawn, then really are the ordinates of curve 1 added to the depreciation. The distances between curves 2 and 3 represent the total cost of the power given out in the successive discharges, and as has already been stated, this increases because the amount put into the battery is the same, but the discharges grow less and less owing to the depreciation of the capacity. As before, these values represent the cost of the total power from the start and not simply for each discharge. These three curves having been drawn over each other, the last one, No. 3, at once represents the sum of all three. It should be remembered, however, that each ordinate of the last curve 3 represents the sum of all the previous costs up to that discharge, thus giving the *total* cost of the battery, the cost of all the depreciation, and of the total energy in all the previous discharges. This summation may be made for every discharge or for every 10 discharges, or in fact for any convenient period, provided only that the period is always the same; the curve is, therefore, really a step by step line, but the steps are supposed to be so frequent that the curve becomes rounded off. Such curves in which all the previous costs are added together up to each discharge, usually rise very rapidly, hence the units of the vertical scale are usually made small, so as to shorten the height of the curve.

Curve *b* simply gives the useful kilowatt hours given out by the battery up to the end of each discharge of its life; here, again, each ordinate is the sum of all the outputs of the battery in all the preceding discharges, that is, it is the total output of the battery from the start up to the end of that discharge.

Curve *c*, which is the ultimate one desired, is obtained by dividing the ordinates of curve *a* by the corresponding ones of curve *b*. By thus dividing the total money paid out up to the end of each discharge, by the total useful energy received from the start up to the end of that discharge, the result will be the *average* cost per useful kilowatt hour delivered between the start and that discharge. This average is at first quite large on account of the first cost of the battery, it then diminishes, but later on rises again on account of the great waste of energy toward the end of the life; hence it has a minimum value at a certain life, as shown by this curve. At that age it is cheaper to renew the battery than to continue to use it, even though it may not seem to be worn out.

When the final curve is relatively flat at and near the minimum point, it means that the minimum point is not sharply defined, and that one may safely go some distance to one side or the other of the theoretical point without affecting the result materially. But if the curve at the minimum point is sharp and pointed, it means that it is sharply defined, and that one should approach the exact point as closely as possible.

As has already been stated, all these curves are intended only to show in a general way how such determinations can be made, they are not intended to give any absolute values. The curves will naturally vary quite greatly with different batteries, and those of Fig. 4 will vary with different costs of the power, and when actual figures are used the minimum point may fall outside of practical limits. For instance, in the last case, Fig. 4, curve *c*, the minimum point might occur at a later time than the natural life of the battery, and it would therefore be impossible to reach this point. But even then the calculation has a value, as it shows conclusively that the life of the battery is shorter than that required to give the best result. If, on the other hand, the minimum point occurs much earlier than the natural life, it shows that the battery has an unnecessarily long life and it would be cheaper to force it, or to make it lighter. In this way such calculations as those here described may often lead one to approach, or even arrive at, the very best conditions of operation or construction.

## CALCIUM CARBIDE AND ACETYLENE.

Calcium carbide, $CaC_2$, was prepared by a purely chemical method in 1862 by Wöhler, who heated an alloy of zinc and calcium with an excess of carbon. The great calcium carbide industry of the present time, however, depends upon the electric furnace process. Calcium carbide was produced in a small way by the Cowles brothers in their electric furnace while it was used in Cleveland. The production on a commercial scale in the United States dates from 1894, when Thomas L. Willson developed the process in Spray, N. C. Since that time the calcium carbide industry has made enormous progress, which was even too rapid in various countries to be sound, and at present it is one of the most important electrochemical industries.

The principal point which decides the economical problem of

... acetylene industry ... to find well-paying ... and application for calcium carbide. The use of calcium carbide as a reducing agent for various metallurgical processes has attracted considerable attention in recent years. This interesting subject shall be dealt with in a separate article in this Journal in the near future. The main use of calcium carbide is, of course, at present the production of acetylene, and the most important problem of the calcium carbide industry is, therefore, at present most intimately connected with the problem of finding new uses for acetylene gas and to extend further the commercial use of acetylene lighting.

We will begin with a very brief review of the chemistry of the subject. Calcium carbide is prepared by heating in the electric furnace a mixture of lime, CaO, and coke. At the high temperature of the furnace, the calcium, which is formed by the action of carbon on lime, unites with carbon and forms calcium carbide, $CaC_2$. Acetylene, $C_2H_2$, is made by decomposing calcium carbide with water, according to the equation

$$CaC_2 + 2H_2O = Ca(OH)_2 + C_2H_2.$$

The combustion of acetylene gas takes place according to the equation

$$2C_2H_2 + 5O_2 = 4CO_2 + 2H_2O.$$

This last equation represents, however, the total combustion process. According to this equation, the combustion would be

WORKS OF UNION CARBIDE CO., NIAGARA FALLS.

bimolecular, while it has been pointed out that chemical processes are almost always mono- or bimolecular, and that in such cases in which a reaction is represented by an equation indicating several molecules it is probable that several intermediate reactions are involved.* Indeed, from a kinetic standpoint, polymolecular reactions should be expected to be rare, because there is only a slight probability of a large number of molecules coming together in just such a way that the reaction can take place. A reaction is much more likely to proceed in a way which involves the interaction of only very few molecules. This has, indeed, been found to be the case with our reaction, as Bone and Cain proved that there are different steps, the first of which is represented by the bimolecular equation

$$C_2H_2 + O_2 = 2CO + H_2.$$

Finally CO and $H_2$ then burn further to $CO_2$ and $H_2O$.

While the calcium carbide and acetylene industries are closely connected, and depend the one upon the other, they are not connected financially, both industries being operated separately and backed by separate capital.

The electric furnace process of making calcium carbide, as worked by T. L. Willson in 1894, was discontinuous. One of the most important improvements in the development of this industry was accomplished by Charles S. Bradley, who made the process continuous. A general outline of the process, as it is worked at present by the Union Carbide Co. at Niagara Falls, was given by J. W. Richards in ELECTROCHEMICAL INDUSTRY, Vol. I, page 22. A large amount of the power of the new water-power plant at Sault Ste. Marie has been contracted for by the same company for the purpose of making calcium carbide. We hope to publish a detailed article on the technical problems in the calcium carbide manufacture in the near future.

Concerning the theoretical yield of carbide furnaces, a number of calculations have been made, which are especially interesting in one point, as they show how different results are obtained in such calculations of the theoretical yield, on account of the uncertainty of the assumptions made. J. B. C. Kershaw has given an interesting summary of the results obtained by nine different authors. The kilowatt hours theoretically necessary to produce one metric ton (2,200 pounds) of calcium carbide, containing 80 per cent. carbide, vary between 1,523 and 3,293 (London *Electrician*, November 23, 1900, pages 164 and 245). The same author also gives figures from actual practice. These figures still vary considerably, but he believes that the most reliable figures for the kilowatt hours necessary to produce one metric ton of calcium carbide, containing 80 per cent. of carbide, is between 3,800 and 4,100 kilowatt hours.

While the calcium carbide industry in the United States is in the hands of a single company, and is developing along steady and conservative lines, the development in Europe, especially on the Continent, was characterized by the sudden erection of a great many plants, with a resulting enormous overproduction. The crisis which then set in was inevitable. Many European calcium carbide plants either stopped operation entirely or undertook the production of other electrochemical products more profitable under the existing conditions. It is estimated that on the European continent, allowing a reasonable rate of increase in the consumption of acetylene, it will probably require ten years before the demand for calcium carbide equals the present manufacturing capacity (*Mineral Industry*, vol. 10, p. 74).

Some remarks on page 453 of volume 8 of the *Jahrbuch der Elektrochemie*, which has just been issued, are very interesting in this connection. It is pointed out that the insufficient demand cannot be considered to be the only reason of the industrial European crisis, but that an important point is the fact that it is not at all easy and cheap to make calcium carbide of the good quality required for acetylene manufacture, especially if the raw materials are not pure.

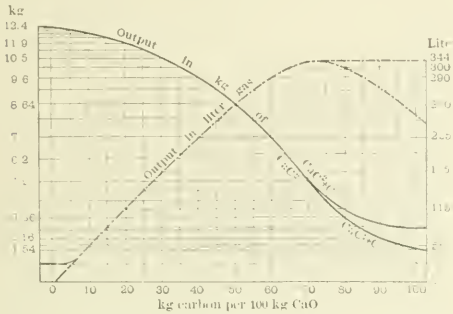
*Mineral Industry* (vol. 10, p. 75) sets forth some important points in this connection, explaining the better condition of the American industry. In Europe the prevailing custom is to remove calcium carbide from the furnaces by the so-called "tapping" process, while in America the ingots are taken directly from the furnace. It is now conceded that a more uniform quality can be produced by the latter method, and the greater purity of the raw materials in America yields a higher grade of calcium carbide than that generally produced in Europe.

An interesting investigation of the relations between the output of calcium carbide and of acetylene under different conditions of manufacture was made by Keller, of the Compagnie Electro-Thermique Keller, Leleux et Cie, in Paris. Its results were presented to the Third International Acetylene Congress in Paris, and may be seen from the adjoining diagram.

In the plants at Meran and Milan, the average current used in the furnaces was 7,500 ampères at 30 volts. The left-hand scale of the diagram gives the number of kilograms of carbide per 24 kilowatt hours; the right-hand scale gives the number of liters acetylene gas (at 760 mm. pressure and 15° C.) per kilogram of "carbide" obtained in that case. The scale of the axis of abscissas gives the number of kilograms of carbon per 100 kilograms of lime put into the furnace. If the mixture used in the furnace consists of 100 kilograms CaO and 65 kilograms C, an output of 6.2 kilograms calcium carbide per kilowatt day and a development of 300 liters acetylene per kilogram

* Holleman Inorganic Chemistry (Cooper) p. 152 and 239.

carbide were obtained. If a mixture of 100 kilograms CaO and 60 kilograms C is used, an output of 7 kilograms CaO per kilowatt day and a development of 200 liters acetylene per kilogram carbide were obtained. This shows that 1 kilowatt day yields in the first case 1,850, and in the second case 2,030 liters of acetylene.




OUTPUT OF CALCIUM CARBIDE AND ACETYLENE.

As we said before, the future of the calcium carbide industry is intimately connected with the future of the acetylene industry, and it is a very favorable symptom that both industries show at present in this country a steady and healthful growth and progress. True, the use of acetylene for power purposes may still be said to be in an experimental stage, and it is doubtful whether the acetylene motor will ever find a very extended use for general power purposes, but the use of acetylene as an illuminant is extending steadily and on a sound basis. This was not always so.

From the beginning, many would-be inventors were attracted by the apparently very simple problem of generating acetylene gas by bringing calcium carbide and water together. The list of acetylene apparatuses patented in Washington numbers about 1,000. It was overlooked that the problem of acetylene lighting must be considered with due regard to the chemical principles of the combustion of inflamable gases.

In the last years the problems involved in acetylene lighting were carefully studied, and the main principles are now well understood, with the result that reliable and safe apparatuses are now on the market. And it seems safe to conclude that, under these conditions, and on account of the excellence of the acetylene light itself, its use will increase steadily and rapidly, especially for certain purposes and in certain parts of the country. The fine display made by the acetylene interests at the Buffalo Exposition has largely contributed to the present growth of the acetylene industry.

## THE STORAGE BATTERY AS AN ELECTROLYTIC CELL.

BY C. J. REED.

All galvanic batteries, whether secondary or primary, are electrolytic cells, although electrolytic cells are not all galvanic batteries.

In order to understand thoroughly the relation of primary and secondary batteries to other electrolytic cells, we must first have a clear conception of the nature of an electrolytic cell, or electrochemical system, as it should more properly be called. We must understand the fundamental process of electrolysis, which is alike in all such systems, and which forms the basis for a definition of electrochemical action.

It may seem superfluous at this late date to revert to such elementary and fundamental principles, but there appears to be a surprising lack of clear conceptions on this subject, even among those who are supposed to know it thoroughly.

A short time ago a certain professor of physics in a well-known university made the statement, in the presence of the writer, that the *slightest external electromotive force* is sufficient to send a current in either direction through any electrolytic cell. On being asked whether this statement applied to an electrolytic cell consisting of an electrolyte of sulphuric acid, a cathode of lead and an anode of lead peroxide, he replied: "Oh, that is a storage battery." This answer showed that, in his opinion, a storage battery was not included in the category of electrolytic cells. His conception of an electrolytic cell was probably limited to an *electroplating* cell.

Conceptions of this kind are our stumbling blocks, and are the source of innumerable, unnecessary hypotheses and assumptions, invented for the purpose of explaining imaginary inconsistencies in nature.

There is no distinction to be made between electrochemical and electrolytic action. Both of these terms define the same fundamental process, which is perfectly distinct from all other processes in nature, and is the characteristic of all primary and secondary galvanic (voltaic) and other electrolytic cells. Not only is this process perfectly definable in terms applicable to all cases, but the mechanism required for its operation is definitely and universally the same.

This fundamental characteristic of electrochemical action is *change of chemical valence or combining capacity* in a particular manner. This change is always produced whenever an electric current passes from an electrode to an electrolyte, or from an electrolyte to an electrode. The change of valence is always in a specific direction at the cathode, and is always of the same quantity and in the opposite direction at the anode; but is never in both directions at the same place. At the cathode the change of valence always tends to liberate an electropositive body from combination, and always tends to cause an electronegative body to enter into combination. At the anode the change of valence always tends to liberate an electronegative body from combination, and always tends to cause an electropositive body to enter into combination. This is the distinguishing characteristic of all electrolytic or electrochemical action, and the only one.

There are other results which generally accompany the passage of an electric current through an electrolytic cell, but they are not characteristic. For example, a particular substance is generally transported through the electrolyte in a particular direction with reference to the current as a result either of the chemical changes or of the current, but this is not always so. Lead, thallium, sulphur, nitrogen, silver, gold, manganese, and many other substances are sometimes transported during electrolysis to the cathode, sometimes to the anode, and some of these substances may be transported towards both electrodes simultaneously. There is no other universal change or effect produced by or in electrochemical action, except the characteristic changes in valence above referred to, which is available for defining electrolysis.

Changes in chemical valence are of frequent occurrence in ordinary thermochemical reactions, but in these cases the opposite changes in valence occur in two atoms or atomic groups which are in intimate molecular contact with each other, while in all electrochemical reactions the atoms undergoing opposite changes of valence are never in contact with each other, but are always at the terminals of a body of electrolyte which intervenes between them, and in which there is no change of valence. Whenever there is a change of valence in any chemical reaction, thermochemical or electrochemical, it is always of the two kinds above mentioned. There never can be an increase of electropositive valence without an equal simultaneous increase in electronegative or decrease in electropositive valence. Nor is there ever a increase in electropositive valence without an equal simultaneous decrease in electronegative or increase in electropositive valence. The essential and universal difference between thermochemical and electrochemical reactions is that, in thermochemical reactions, these two oppo-

changes of valence take place in two individual atoms or atomic groups which are at the same place and in contact, the energy change being from chemical energy to heat and from heat to chemical energy; while in electrochemical reactions the two opposite changes of valence take place in atoms or molecules which are not in molecular contact, but are physically separated by an intervening compound conducting body, which undergoes no change of valence, the energy change being from chemical energy to electrical or from electrical into chemical energy.

Having accepted this conception of the nature of an electrolytic cell we are prepared to consider the relation between storage batteries and other electrolytic cells.

The difference between galvanic batteries (whether primary or secondary) and other electrolytic cells is entirely one of energy. In the nature of the electrolytic process there is no difference whatever.

In every chemical change there is always a transformation of energy. Either chemical energy is converted into another form or some other form of energy is converted into chemical. There are chemical changes in which no changes of valence occur, but we are not particularly concerned with changes of this character. They are called reactions of double decomposition, and the energy transformed in reactions of that kind is always comparatively small. In chemical reactions resulting in changes of valence, there is generally a transformation of a large amount of energy. In all chemical changes the transformation of energy must take place where the change in matter occurs. In a thermochemical reaction the transformation of this energy must all occur at the single point where the two reacting molecules or atoms undergoing the change of valence are brought in contact. In electrochemical reactions the transformation of energy corresponding to any change of valence must also occur at the point where the matter undergoing the change is located. We have seen that in electrochemical changes the changes in matter must necessarily occur at *two* different points. Hence, in an electrochemical action the transformation of energy must always occur at two different points, namely, at the terminals of the electrolyte; that is, at the two junctions of the electrolyte with the electrodes, where the corresponding changes in matter occur. The quantity of energy transformed at each of these two points will, in all cases, depend upon the nature of the substance undergoing a change of valence and the energy corresponding to such change. In such changes the energy transformed, or at least a great part of it, will always be in the form of electrical energy, either before or after the transformation; whereas in thermo-chemical reactions it will always be in the form of radient energy (heat or light).

In the electrochemical reaction, however, the electrical energy, if it appears after the transformation, may be immediately converted into heat by bringing the electrodes electrically to the same point; that is, by connecting them with an electrical conductor of low resistance, or by short circuiting the cell. In this case the energy (heat) is evolved not only at the two electrolytic junctions, but throughout the entire system, as it would be in a thermo chemical reaction, with the reacting components uniformly distributed.

The current strength is always the same at both electrodes of an electrochemical cell, and therefore an electromotive force must always be either developed or absolved at each electrode proportional to the transformation of chemical into electrical or of electrical into chemical energy at that electrode.

It follows from the above statements that, in any electrolytic cell, there is always developed at an electrode an electromotive force tending to increase the current, if chemical energy is changing into electrical energy at that electrode; that is, if the change of valence diminishes or dissipates chemical energy, and an electromotive force opposed to the current if electrical energy is changing into chemical energy; that is, if the change of valence at the electrode increases or accumulates chemical energy.

It is evident that electrical energy may be evolved at one electrode of an electrolytic cell and simultaneously absorbed at the other; that it may be evolved at both electrodes simultaneously or absorbed at both electrodes simultaneously, and it is further evident that the quantities of energy evolved or absorbed at the two electrodes may be equal or unequal, depending upon the nature of the substances concerned in the reaction.

Remembering that whenever electrical energy is evolved, chemical energy disappears, and whenever electrical energy is absorbed, chemical energy is generated, we see that, if the sum of the changes at the two electrodes evolves electrical energy, the cell or system as a whole is acting as a source of electrical energy, or it is a galvanic battery in the process of discharging. If the sum of the changes at the electrodes absorbs electrical energy, the system is acting as an accumulator or generator of chemical energy. If the chemical change at one electrode is equal and opposed to that of the other, as, for example, when the chemical change at one electrode is reversed at the other electrode, the cell as a whole will neither generate electrical energy nor accumulate chemical energy. Such a cell can neither oppose an electrochemical electromotive force to the passage of a current in either direction nor produce a current in either direction. A cell of this kind requires for the passage of an electric current through it, an external electromotive force sufficient only to overcome the resistance of the materials and the thermo-electromotive forces generated by the current itself. Electrolytic cells of this kind are, in common parlance, generally called simply "electrolytic cells," but have no specific name to distinguish them from batteries.

Electrolytic cells which are capable of generating electrical energy at the expense of their chemical energy have, from that circumstance, received the general name of batteries. The writer has suggested elsewhere that electrochemical systems which generate neither electrical nor chemical energy be called *agenic*.*

Every electrolytic cell which generates electrical energy when a current passes in one direction will generate chemical energy when the current passes in the opposite direction. Every cell, therefore, which acts as a battery when the current is in one direction is necessarily a generator of chemical energy when the current is in the opposite direction. Such cells the writer has described as *electrogenic* when they are generating electrical at the expense of chemical energy (discharging), and *electrothanic* when they are generating chemical at the expense of electrical energy (charging).

The question often arises as to what constitutes the difference between a primary and a secondary or storage battery. There is evidently no difference at all in the cell, but a difference only in *the manner of using* the cells and in their origin. If a battery is manufactured without the aid of an electric current, and is thrown away after its chemical energy is once dissipated, it is called a primary battery. If the cell has its chemical energy restored after discharge by passing a current in the opposite direction, it is called an accumulator or storage battery.

There is a distinction to be made, however, between accumulators and storage batteries. An apparatus may generate chemical energy without actually storing it. The fact that every galvanic battery will generate chemical energy when a current is passed through it in the direction opposed to its electromotive force does not signify that it will necessarily *store* the chemical energy thus generated. Herein lies the practical difference between a primary battery and a secondary or storage battery. There are very many cells in which this generated chemical energy is not available for the generation of electrical energy, on account of the purely accidental circum-

* "Electrochemical Action," Journal of the Franklin Institute, May June, 1901.

stance that the chemical products formed are mechanically lost in the process of generation. These accidental mechanical losses of material in certain cells or types of cells, however, do not constitute an essential feature on which a classification of electrochemical cells into reversible and non reversible should be founded. Such a classification implies that there are non-reversible electrochemical reactions, which is not true.

If any of the products of the electrochemical reaction formed in charging or discharging a battery are allowed to escape as a gas, or allowed to fall out of the electrolyte as an insoluble precipitate, or are allowed in any other manner to get out of the circuit, they cease to be a part of the electrochemical system, and, of course, cannot be available in that system for a subsequent operation.

In order to illustrate the foregoing statements by a familiar example, let us assume an electrochemical system to consist of an electrolyte of dilute sulphuric acid and electrodes of platinum. On passing a current through this system, the electrochemical changes at the electrodes will form at the cathode a hydride of platinum, and at the anode an oxide of platinum, the oxygen and hydrogen being derived from the decomposition of the electrolyte. These compounds of platinum have now become the electrodes of the system, and have replaced the original platinum electrodes, the platinum having been exhausted in the formation of these platinum compounds. This electrochemical reaction absorbs electrical and generates chemical energy, the electromotive force required being slightly more than one volt. If the circuit be now opened and the system examined, it will be found to be a source of electrical energy; in other words, a battery, the platinum hydride acting as the anode and the platinum oxide as the cathode in discharging. Its electromotive force will be approximately one volt at the beginning of discharge.

If, instead of interrupting the current when the platinum electrodes have been exhausted by conversion into compounds of platinum with oxygen and hydrogen, we allow the current to continue, an entirely different electrochemical reaction will take place. There being no more platinum to combine with either oxygen or hydrogen, and there being no other substance present at the terminals of the electrolyte capable of undergoing any chemical change under these conditions, the electrolyte itself must decompose in the easiest manner, liberating hydrogen at the cathode and oxygen, hydrogen peroxide or persulphuric acid at the anode.

The electric current, in crossing the junction between an electrode and an electrolyte, must be transmitted by the ions which undergo the electrochemical change. This is equivalent to saying, in the language of current theories, that the ions themselves must receive or give up the electric charges which constitute a current. It is evident, therefore, that these ions on being eliminated from the electrolyte, or on going into the electrolyte, must actually conduct the total current. It is a well-known fact that oxygen and hydrogen in the gaseous state are very perfect *non-conductors*. The resistance of these substances in the gaseous state under ordinary atmospheric pressure is known to be so high that they could not in that state possibly transmit the current of such a cell without opposing a resistance enormously greater than that which has been observed.

The evidence is, therefore, conclusive that these oxygen and hydrogen ions in the particular case under consideration are not rejected at the electrodes in the ordinary gaseous form, for example, as bubbles of gas. This would be impossible, since the total current would have to be transmitted by these bubbles of gas, and not by the surrounding electrolyte. We must conclude, therefore, that these ions are rejected *in solution* as dissolved gases, in which state they may act as conductors, since, owing to their low coefficients of solubility, they would be in a highly-attenuated state, in which condition they are known to be conductors. It is also reasonable to assume that these gases in solution would conduct the current independent of any attenuated state, since many other substances have been found which conduct in solution and do not conduct in the solid or gaseous state. The fact that these products of electrochemical reaction appear as bubbles of gas, and are formed in large quantities, is easily explained, since the elimination of these substances in solution by the current would soon cause supersaturation. The gases would then be spontaneously evolved in the form of bubbles, exactly as carbon dioxide or any other gas is evolved from a supersaturated solution.

In this case, in which oxygen and hydrogen are evolved, it is evident that after these gases have passed out of the solution in the form of bubbles of gas, the chemical energy stored in them cannot be used in a subsequent operation of the apparatus, unless provision is made for collecting the gases and restoring them again to the solution when needed.

This was done by Grove in his celebrated gas battery by inverting closed tubes over the platinum electrodes to collect the evolved gases and retain them in contact with the electrodes and the electrolyte surrounding the electrodes. In this particular case the chemical energy generated in forming the platinum compounds is the only energy available in the subsequent discharge. In discharging this cell, the platinum hydride and platinum oxide are the electrochemical reagents which generate electrical energy in being changed again to platinum and in forming additional molecules of water. But platinum has the property of combining spontaneously at ordinary temperatures with either oxygen or hydrogen on coming in contact with these substances. Therefore, as the platinum hydride and platinum oxide become exhausted in generating electrical energy, the residual platinum in the Grove battery immediately absorbs the surrounding gases, both that in solution adjacent to the platinum surface and that in the reservoir above the solution surrounding the platinum plate. The platinum oxide and platinum hydride are, therefore, spontaneously formed from the stored gases as the discharge proceeds, and this process continues until the gases are exhausted. The oxides and hydrides of platinum formed in this manner are formed thermochemically, however, since the platinum is an actual contact with the gas, and the energy of these combinations is lost as heat. The electrical energy obtainable from the discharge of this cell is therefore less than that required to evolve the gases by the amount of this heat. The electromotive force of the Grove battery is, on this account, only about 1.08 volts, instead of 1.47 volts.

Although every electrochemical reaction is perfectly reversible, the reversibility is not always apparent. Owing to the fact that in most electrochemical systems several reactions take place simultaneously, which are entirely independent of each other and produce different products, an electrochemical system sometimes produces a chemical reaction with the current in one direction, which does not appear to be reversed when the current is in the opposite direction. This apparent irreversibility is due in many cases to the fact that when two or more reactions take place simultaneously at the same point, the reaction which takes place more easily with the current in one direction, reverses most difficulty with the current in the opposite direction.

Another cause of this apparent irreversibility is the mechanical construction of the cell, which is not always such as to preserve the system and retain the products of one reaction in the position required for complete reversal. Another cause which sometimes prevents reversal is the action of selective chemical affinities in the products formed, which may, by secondary reaction, destroy these products.

While all electrochemical reactions are reversible this does not imply that the process or nature of the electrochemical change is of an opposite kind. The nature of the electrochemical change is always the same.

It is frequently stated that the charging of a storage battery is reversing the process of discharge. The process is exactly

the same on discharging as on charging. The only thing changed is the electrode originally peroxide becoming the anode and the anode becoming the cathode. In charging a lead accumulator, lead sulphate is changed into lead peroxide at the anode, the electropositive valence of the anode being thereby increased; and similarly the lead sulphate is reduced to metallic lead at the cathode, the electropositive valence being diminished. In discharging, the reduced electrode becomes the anode, and the lead peroxide electrode becomes the cathode. In this second process again, the electropositive valence of the lead anode is increased and the electropositive valence of the lead peroxide cathode is reduced, so that in both cases the electropositive valence of the anode is increased and the electropositive valence of the cathode is reduced. If the discharging reaction is carried to completion, the material is all converted into lead sulphate. If, from this point the reaction is continued in either the same direction or in the opposite direction, we still continue to have an increase of electropositive valence at the anode and a decrease of electropositive valence at the cathode; but, instead of the formation of lead sulphate from peroxide and metallic lead, we have the formation of peroxide and metallic lead from the sulphate, not because of any reversal of the process but because we have different materials constituting the electrochemical system. In the beginning of discharge we have a peroxide cathode and a metallic lead anode; at the end of discharge we have a lead sulphate cathode and a lead sulphate anode. If the current is continued now in either direction, we have a system in which the anode is lead sulphate and the cathode lead sulphate. With these electrodes, the current in either direction necessarily produces lead peroxide at the anode and metallic lead at the cathode. We see, therefore, that changing the direction of the current in charging and discharging is not the reversal of an electrochemical process, but must be considered merely a reversal of material used as electrodes and produced as products. In other words, it is the *matter* which undergoes changes and reversals of combination, and not the process. We cannot expect to obtain, when we subject metallic lead to a certain process, the same products as would be obtained by subjecting lead sulphate or lead peroxide to the same process. The process of electrochemical change should always be considered as the same, namely, increase of electropositive valence or decrease of electronegative valence at the anode, and increase of eletronegative valence or decrease of electropositive valence at the cathode. There is no known exception to this statement.

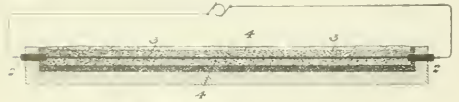
# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl.

ELECTRIC FURNACES AND FURNACE PRODUCTS.

*Process of Making Graphite.* Edward G. Acheson, Niagara Falls, N. Y. Patent No. 711,031, October 14, 1902. Application filed December 22, 1900.

In this specification Mr. Acheson discloses a new method for the production of graphite from carbonaceous material. Heretofore his process consisted essentially in subjecting carbon, mixed either naturally or artificially with materials capable of forming carbides, to the intense heat of the electric furnace. A perfect transformation of amorphous carbon into graphite may however, be brought about by causing metallic vapors to act upon the amorphous carbon at the high temperature obtainable in an electric furnace. This may be accomplished by mixing metals or metallic compounds with the charge of carbon, then volatizing the metals or compounds by the intense heat, and thus causing the metallic vapors to permeate the mass of carbon. Various forms of amorphous carbon may be used and various metals or compounds employed for generating metallic vapors, such as iron, silicon, titanium, aluminium, boron or their compounds. The furnace used in the operation is shown in cross section in the adjoining Fig. 1. So-called petroleum



CHEMICAL GRAPHITE FURNACE.

coke, the residue obtained from the distillation of petroleum oil, is crushed to such a size that its particles vary in size from a powder to lumps 3 to 4 inches in diameter, and is preferably so arranged that the lumps are completely imbedded in the powder. Oxide of iron, in the proportion of 5 pounds of iron to 100 pounds of coke, is roughly mixed with the petroleum coke. The two electrodes 2, 2 are introduced through the ends of the furnace, and carbon rods 3, 3 are arranged between them to serve as preliminary conductors of the current. The entire charge 4 is preferably covered with a layer of material which does not conduct heat, such as sand and powdered carbon in proper proportion to form carbide of silicon. With a furnace 30 feet long, 14 inches wide and 18 inches deep, a current of about 200 volts and 300 ampères is suitable. As the temperature increases, this current rises quickly, on account of the reduced resistance of the carbon rods and the coke. The completion of the furnace operation is indicated by a great reduction of the resistance. During the operation the oxide of iron is reduced to metal, which either is held in the cavities or spaces between the lumps of carbon or drops to the floor of the furnace. Afterwards, as the temperature rises, the metal is volatilized, and, coming into intimate contact with the carbon, effects its conversion into graphite. After the operation the furnace is allowed to cool down, the covering of sand and carbon, which has been partially converted into silicon carbide, is removed and the coke, which has been converted into soft graphite carbon, is taken out. It is interesting to note in this connection that petroleum coke, when treated by Mr. Acheson's earlier method, was considered to graphitize very poorly (J. W. Richards, Electrochemical Industry, Vol. I, page 53). See also an article by Danneel in the *Zeit. f. Elektrochemie*, September 25, 1902, which treats about this subject, and has been abstracted in Electrochemical Industry, Vol. I, page 106.

*Object of Refractory Material and Method of Manufacturing Same.* Charles B. Jacobs, East Orange, N. J. Patent No. 711,319, October 14, 1902. Application filed December 26, 1900.

According to the inventor, who is connected with the Ampère Electrochemical Co., Niagara Falls, N. Y., this invention has for its object to provide in a commercial form bricks, tiles, blocks or other material of definite shape and of materials such as are not fusible in ordinary furnaces or ovens; for example, the silicates of aluminium and similar refractory silicates. The materials are melted in the electric furnace and cast into molds. It is stated that, in the application of the process to certain materials, such as aluminium silicate, the heat volatilizes a portion of the more volatile constituent (silica), the remaining material being less fusible, harder and tougher than the original material. Fire clay or kaolin is charged into an ordinary furnace, and an arc started between the electrodes and maintained until the mass is fused. In case kaolin or a refractory silicate is being treated, the inventor prefers to continue the heating current for a sufficient time to drive off, in the form of white clouds, a substantial percentage of the silica present in the

material. Thus the kaolin ($Al_2O_3 \cdot 2SiO_2$) is changed to the normal silicate $Al_2O_3 \cdot SiO_2$. With 200 pounds of material and a current of about 100 volts and 1,500 amperes, it takes about twenty minutes to melt the clay and about forty minutes more to drive off half the silica, so as to leave the normal silicate. This chemical change is accompanied by a very important physical change, namely, an increase of the hardness and toughness and a decrease of the fusibility of the resulting material. If the original material (fire clay) be simply fused and, without the loss of any of its silica, be allowed to cool to solid state, it will present a glossy appearance and be very brittle, but if maintained in a fused state for a sufficient time to lose a substantial or appreciable percentage of its silica, it will cool to a waxy-looking mass of an extreme degree of toughness and hardness. The molten material is poured through a tapping hole in the bottom of the furnace into metal molds. The chilling effect of the metal of the mold causes a thin crust of solidified material to be formed on the surface of the metal, and thus protects the mold from the action of the intensely-heated mass. A material like this would undoubtedly be very valuable for a good many purposes. For ordinary metallurgical uses it might, however, prove to be too expensive, as energy at the rate of 150 kilowatts per hour has to be expended in order to convert 200 pounds of material into the desired product, though the increased cost might be counterbalanced by the increased durability of the material.

*Process of Manufacturing Ferrosilicon and Silicospiegel.* Gustave Gin, Paris, France. Patent No. 712,025, November 4, 1902. Application filed April 17, 1901.

The process outlined in this specification concerns the manufacture of ferrosilicon and silicospiegel. It is proposed to use as raw material the silicon slags from metallurgical operations in the converters for the Bessemer acid process or in the Martin furnaces with silicon coatings. These slags contain, according to the specification, almost the whole of the elements which are more oxidizable than iron, and especially the metals of the alkaline earths—silicon, titanium and manganese—which existed previously in the ore or have been introduced during the process. It is stated that by regenerating these elements it is possible to obtain from by products, which are generally worthless, silicides of iron or manganese, "which enable a new cycle of refining operations to be carried on." The specification shows a number of errors in scientific terminology, such, for instance, as the continuous reference to the Martin furnaces with silicon coating, the designation of silicon, titanium and manganese as metals of the alkaline earths, the assertion that the composition of the slag of the acid Bessemer furnaces is silicate 50.82 per cent., alumina 3.15 per cent., etc. At another place it is said: "It has been proposed to extract from the blast furnaces slag carbid of calcium and cast iron, but this use is not in affinity with the particular manufacture of silicides obtained with a particular slag." It is hard to find out what particular idea is meant to be conveyed by this statement. The operation of the process itself is described as follows: "Let it be supposed that the slags to be treated come from the Martin furnaces having acid linings, and that they have the following composition: $SiO_2$, 50.42; FeO, 34.10; MnO, 0.92; $Al_2O_3$, 2.20; CaO, etc., 3.30, which may correspond per ton to the following formula: 8,400 SiO (?) + 3,800 FeO + 1,400 MnO + 220 $Al_2O_3$ + 600 CaO. I add to the slag, which has been pulverized, a quantity of carbon, so that the mixture contains one molecular proportion of carbon for each molecular proportion of oxygen in the silicate (?) and the iron and manganese peroxides without taking care of the alumina and the oxides of alkaline earths. To the slag under consideration it will therefore be necessary to add 8,400 + 2 + 3,800 + 1,400 = 22,000 atoms (?) of carbon. This can be done by introducing to the previously pulverized slag the required quantity of coal, etc. The mixture is then subjected to the heat of a continuous or alternating-current electric furnace. The most favorable voltage ranges from 25 to 30 volts and the power density (the number of volts per square centermetre of the perpendicular cross section of the electrode) should not exceed 70 volts if it be wished to reduce to its lowest practical limit the volatilization of the silicon and the manganese. Under these conditions there are not metallic carbides produced, but a bath of ferrosilicon or silicospiegel is obtained, which is run into ingot molds at intervals. In order that the operation may be carried on continuously, it will suffice to feed the electric furnace regularly with the aforesaid mixture." The derivation of the formula given above is not explained. The slag, metallurgically considered, corresponds very closely to a sesquisilicate, having a ratio of oxygen of the bases to oxygen of the silica of nearly 2 : 3. Consequently its formula would come close to $4RO, 3SiO_2$, designating by RO the monosides FeO, MnO, etc., present in the slag. Mr. Gin has had a great deal of experience in the running of electric furnaces for the manufacture of calcium carbide, and is one of the inventors of one type of them, the Gin & Leleux furnace, and the burden of proof now rests on him to show that he can produce ferrosilicon and silicospiegel economically by this process.

*Dentists' Electrical Annealing Furnace.* Nathan K. Gerhart, Indianapolis, Ind. Patent No. 712,057, October 28, 1902. Application filed August 22, 1902.

The object is to produce an efficient electric annealing furnace, particularly for the use of dentists. The heat is furnished by electric resistance coils, situated below a heating surface of isinglass or other suitable material. The articles to be heated are laid upon this surface, and are heated by radiation. Various mechanical details of the apparatus are shown, adapting the furnace specially to the use of dentists.

### APPARATUS AND PROCESSES FOR THE ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

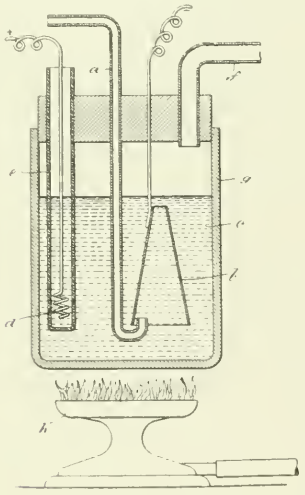
*Process of Converting Salt Marsh Material, etc., into a Fertilizer and the Product Resulting Therefrom.* J. J. Crooke, New York, N. Y. Patent No. 712,044, October 28, 1902. Application filed February 21, 1902.

The object is the conversion of the material of the so called salt marshes or salt meadows into a fertilizer. This material though it contains a great amount of humus and other compounds which would make it valuable as a fertilizer, cannot be used as such on account of certain acids, as gallic, tannic, acetic or sulphuric acids, and compounds like iron sulphide, sulphuretted and carburetted hydrogen, or an excess of chlorides, being present in it. It is proposed to subject it to electrolytic action in a wooden tank, preferably of rectangular shape, having a capacity of about 5 tons of material, and provided with an electrode at each of its sides, consisting of wrought sheet iron and arranged as a lining to the sides of the tank. The material is charged into the electrolyzer in a wet condition, and subjected to electrolysis for three to five hours. The inventor makes the remarkable statement that hydrogen is given off at the anodes, besides hydrogen sulphide, carburetted hydrogen and chlorine. The current is to be continued until the acid reaction at the anode has become neutral or alkaline. When the operation is completed, the charge is taken out, dried and pulverized, and is then ready to be used as a fertilizer. The invention is said to be applicable not only to the material from salt marshes, but also to that obtained from peat bogs, muck bogs and the dredgings of harbors, bay- and the mouths of rivers. Sheet iron anodes in the presence of chlorine will not last long, and the process seems to involve a considerable expenditure of electrical energy in comparison with the value of the finished material.

*Manufacture of Ether.* J. W. Harris, Ashboro, Pa. Patent No. 711,565, October 21, 1902. Application filed June 5, 1902.

The process relates to improvements in the manufacture of ether, which hitherto has been manufactured by mixing alcohol

with sulphuric acid, thus forming ethyl-sulphuric acid, $C_2H_5$. $HSO_4$, and then slowly adding more alcohol, which reacts with the ethyl-sulphuric acid according to the equation $C_2H_5$. $HSO_4$ + $C_2H_5$. $OH = C_2H_5$. $O$. $C_2H_5$ + $H_2SO_4$. The invention consists in the manufacture of ether directly from acetylene, thus dispensing entirely with the use of expensive alcohol. The adjoining figure shows a cross section of the apparatus in which the electrolysis is carried out. It is an ordinary cell *g*, filled with the electrolyte *c* and heated by a burner *h* to the required temperature. The cathode *b* has the shape of a cone, open at its apex, and the spiral anode *d* is surrounded by a tube or porous cell *e*. The acetylene gas enters the tube *a*, bubbles through the electrolyte and passes over the surface of the cathode *b*. The distillate passes off through the tube *f* to a second electrolytic cell, or to others if required. When passing over the cathode, the acetylene is said to combine with the nascent hydrogen liberated by the current to form ethylene and ethane, as expressed by the formula $C_2H_2 + 2H = C_2H_4$, $C_2H_4 + 2H = C_2H_6$. It is important that the production of ethane be restricted as much as possible. The electrolyte, consisting of sulphuric acid containing up to about 35 per cent. of water, is decomposed, the hydrogen acting on the acetylene and the

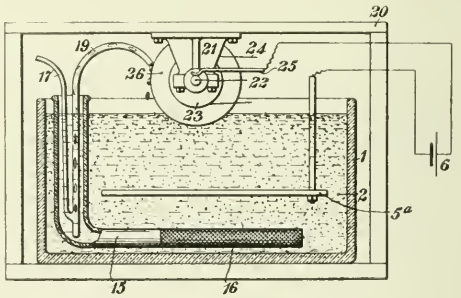



ETHER APPARATUS.

oxygen going to the anode. The ethylene formation takes place in the strong sulphuric acid, and it combines at once with the acid to form ethyl sulphuric acid, $C_2H_4 + H_2SO_4 = C_2H_5$. $HSO_4$, which combination takes place preferably at a temperature above 100° C. Water may be supplied to the cell to keep the concentration of the acid constant, or the acetylene gas may be saturated with water before entering the cell. The ethyl-sulphuric acid decomposes into products which vary with the temperature and the quantity of water present. When the water content exceeds 50 per cent., alcohol is generated. As the water content decreases, the per cent. of alcohol decreases, while that of ether begins. The alcohol formation grows less and less as the water content becomes smaller. The other formation continues until the water content is less than 10 per cent. This formation of ether is due to the reaction between two molecules of ethyl-sulphuric acid and one of water, as expressed by the equation $2C_2H_5$. $HSO_4 + H_2O = (C_2H_5)_2O + 2H_2SO_4$, the electric current assisting this to take place. It is stated that reactions forming alcohol, and subsequently ether, as expressed in the equation (1) $C_2H_5$. $HSO_4 + H_2O = C_2H_5$. $OH + H_2SO_4$, and (2) $C_2H_5$. $HSO_4 + C_2H_5$. $OH = (C_2H_5)_2O + H_2SO_4$, may also take place; but that the fact that the formation of alcohol decreases when the water content is less than 50 per cent., while the formation of the ether begins, indicates that the reaction between two molecules of ethyl-sulphuric acid and one of water is the more probable. The object of the porous diaphragm around the anode is to prevent as much as possible the oxidation of the ethyl-sulphuric acid by the oxygen liberated there. The process is an interesteing one, and if it can be carried out successfully on a commercial scale will be another step forward in the application of the electric current in the field of organic chemistry.

*Method of and Apparatus for Electrodeposition of Metals.* C. J. Reed, Philadelphia, Pa. Patent No. 712,153, October 28, 1902. Application filed August 1, 1901.

The object is to effect the uniform deposition of metals in a hard and compact form, polishing them at the same time. The apparatus is charged with a mixture of a suitable electrolyte and a granular polishing or abrading material, such as sand, for example. The cathode is arranged to be rotated, and thus comes into contact with the abrading material. One form of apparatus, intended for the electroplating of a cylinder, is shown in the adjoining figure, in which 1 is a tank or receptacle charged with the mixture 2 referred to above, and provided with an anode 5a of any suitable shape. The cathode 26 is a cylinder, mounted on a shaft 22, suspended from journals 21 and driven by pulley 23 and belt 24. It is connected by a brush



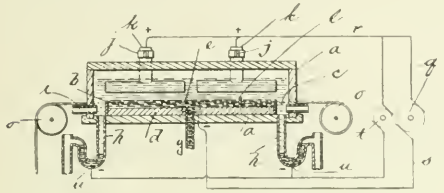

ELECTRODEPOSITION OF METALS.

25 to a suitable source of energy 6. A pipe 15, having a sieve construction 16 at its ends, is arranged on the bottom of the apparatus. Air or gas is supplied under pressure to pipe 17, thus providing effectually for the circulation of the electrolyte. Another apparatus illustrated in the specification shows the same principle applied to the simultaneous electroplating of a large number of small articles, such as tacks, buttons, articles of jewelry, etc.

*Electrolytic Cell.* A. E. Truesdell, Pittsfield, Mass. Patent No. 712,218, October 28, 1902. Application filed April 13, 1901.

The apparatus belongs to the type of mercury cells for the electrolysis of solutions of salts of the alkali metals. The cell, as shown in cross section in the adjoining diagram, consists of a slate or earthenware vessel *a*, provided with a rib *b* running parallel to each of the longer sides, thus leaving channels *c* between the sides and the side of the vessel. The mercury *e* rests on a floor *d* of cast iron. Anodes *k*, with contact pieces *j*, serve to conduct the current into the solution. For the removal of the amalgam formed by the action of the current, a sweep *l* is provided, which brushes the amalgam over the ribs *b* into the channels *a*, which slope down towards the pipes *h*, in which the amalgam accumulates. The pipe *g* serves to supply the apparatus with fresh mercury from a reservoir, in order to keep the level of the mercury at a certain height. The sweep *l* is moved by means of wires passing over pulleys *o* and introduced into the cell through stuffing boxes. It is said that the

sweep can be dispensed with, and the removal of amalgam be effected by raising the level of the mercury in the reservoir, thus forcing a certain amount of it over the ribs *b* into the channels. It is questionable whether this would have the desired effect in an apparatus large enough to be operated on a commercial scale. The main source of current is located at *g*, but, in order to prevent the discharge of amalgam in the pipes *h*, an auxiliary current is introduced, supplied from *t*, and hav-



MERCURY CATHODE CELL.

ing its minus pole connected to the amalgam at *u*. It is doubtful, however, whether a reaction of the amalgam with the solvent could be prevented, even by the introduction of a second current, if it is highly charged and stays in the pipe for some time. The admission of fresh electrolyte to the cell takes place through pipes *i*. There is nothing mentioned about the discharge of the amalgam, which evidently has to be accomplished in another apparatus. The means shown for moving the sweep, by wires passing through the electrolyte, suggest more a laboratory scale of operation than a commercial apparatus, as they probably would not last long in an electrolyte charged with chlorine, and by their solution would speedily contaminate the electrolyte.

*Electric Refining of Lead and Lead Alloys.* A. G. Betts, Lansingburg, N. Y. Patent No. 713,277, November 11, 1902. Application filed January 9, 1902.

The object is to provide a suitable electrolyte for the purpose of electrodepositing lead in a dense and coherent form. The inventor uses as electrolyte a solution proposed by him in a former patent, with the addition of one or more reducing agents. The electrolyte is an acid solution of lead fluo silicate, and among the reducing agents which he finds available are gelatine, pyrogallol, resoicinol, saligenin, orthoamito phenol, hydroquinone and sulphurous acid. Phenols of the aromatic series are said to be well adapted, by reason of their being easily oxidized. Of the above reducing agents, he has found gelatine to be the cheapest and to give the best results, and prefers to use it in the proportion of one pound of gelatine, by weight, to 5,000 parts of the solution. The gelatine is dissolved in hot water and added to the solution in the desired proportion. The presence of the reducing agent in the solution, it is said, serves to restrain the crystallization of the electrodeposited lead, and causes it to form upon the cathode in a solid body of uniform structure throughout. In this way the formation of short circuits, due to the crystallization of the electrodeposited lead, is obviated, and a product obtained which, by reason of its physical properties, facilitates the practical electrolytic refining operations, and may be fused without the formation of an undue amount of dross. The beneficent effects of the addition of the reducing agents are said to be also visible at the anode, where they preserve the mass of lead underneath the anode slime with a somewhat smoother surface. A plant for the carrying out of the process on a commercial scale, with a capacity of about 10 tons per day, is described by Ulke in the *Engineering and Mining Journal*, October 11, 1902 (see the abstract in ELECTROCHEMICAL INDUSTRY, Vol. I, page 105).

*Electrodeposited Lead.* A. G. Betts, Lansingburg, N. Y. Patent No. 713,278, November 11, 1902. Application filed October 9, 1902.

This specification is almost identical in phraseology with the preceding one, but claims the product obtained by the process described above. Claim 42 reads: "I claim ..... as a new product, electrodeposited lead characterized by substantial purity, coherency and uniformity of structure throughout, practically free from crystallization and having substantially the homogeneity, with a density of about 11.3, and retaining the normal structural characteristics due to electrolysis."

STORAGE BATTERIES.

*Accumulator.* Jean Baptiste Relin, Levallois-Perret, France. Patent No. 711,122, October 14, 1902. Application filed December 4, 1901.

The specification describes in detail the construction of a storage battery plate with the object of obtaining the maximum surface. The plates consist of a frame, usually rectangular, to which are fastened strips of lead rolled up in spiral form, having the shape of a double-spiral wood auger. The spiral slips really form the plate, as the frame serves only to support them. They are flattened down so as to form an indented strip, which is nearly flat, but provided with small projections for retaining the active material and facilitating the circulation of the electrolyte. This flattening down is performed by covering each row over with sea salt or any other substance which is hard but can be easily dissolved out. The strips are then placed in a press and partly compressed, so as to leave projections on their surface. The object of the salt is said to be threefold: to preserve the projections of the strips, to form on their surface a large number of small hollows very suitable for the formation of the active material and to clean the surface of the lead and to make it more sensible to the action of the electrolyte. After putting the plates into water, for the purpose of dissolving the salt, they are subjected to the action of a current in an electrolytic bath for their formation, or they may be filled with active material.

*Storage-Battery Plate.* N. T. Daboll, New London, Conn. Patent No. 711,481, October 21, 1902. Application filed February 10, 1902.

The object is to construct a plate of reduced weight per unit of electrical energy, and to materially reduce the operations required in forming the plate. The inventor constructs the plate out of wire gauze, coated with finely divided carbon, and then covered with white lead. The plate is a sort of flat pocket, fashioned out of iron or steel wire gauze. It is filled with finely-shredded steel, and held together by wires passed through opposite sides, in the manner of tacking a mattress. This structure is then coated with a paste, consisting of finely divided carbon made into a paste by a watery solution of any hydrocarbon—sugar, for instance—as a binder. This paste is dried, and then carbonized by the action of heat. To complete the plate, the structure is then coated with white lead and allowed to dry. This plate is certainly new, but there may be doubt about its usefulness for practical purposes.

*Storage Battery.* Frederick Sedgwick, Chicago, Ill. Patent No. 711,537, October 21, 1902. Application filed August 2, 1902.

This patent embodies another attempt at the solution of the problem of obtaining the greatest possible amount of plate surface with the least possible weight of material. The inventor builds up his electrodes from a number of exceedingly thin sheets of lead, about 2-1,000-inch in thickness. In order to provide for the circulation of the electrolyte, these sheets are first prepared by producing on them a large number of small perforations, not less than about 3,000 for each square inch of surface. These perforations are carefully distinguished from mere holes or punctures, and are made by placing the film of lead foil upon the face of a die, provided with fine longitudinal and transverse grooves, between which are projections having minute raised points. A piece of leather is then laid on the foil, and the whole subjected to pressure, thus producing in the foil a uniform series of indentations. The

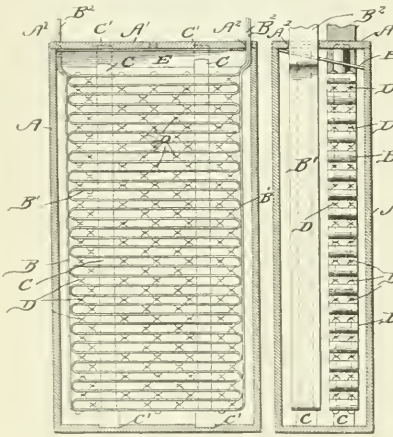
points of these pedestals are then planed or filed off, and the top thus prepared shows a regular series of minute perforations, corresponding to the raised points of the die. The surface is further roughened by means of minute grooves or indentations, and it is claimed that, when the foils are assembled, they form a wick-like cellular mass, through which a free and uniform circulation of the electrolyte may be induced by capillary attraction, allowing the gases to escape as fast as formed. The sheets or films of lead thus prepared are soldered at the top to a lead binding strip, provided with lugs for the necessary connections. Narrow strips of vulcanite or other non conducting material are inserted between the electrodes to serve as separators and prevent short-circuiting. It seems that, though the object of providing a large amount of plate surface is realized, it was attained by a more or less complicated series of operations, involving the handling of a large number of extremely thin lead foils, with its consequent practical disadvantages.

*Storage Battery.* Daniel E. Wiseman, Chicago, Ill. Patent No. 711,710, October 21, 1902. Application filed March 12, 1901.

The inventor constructs a plate consisting of one single long and narrow strip of lead, bent back and forth upon itself in serpentine form, as shown in the adjoining figure, where B' represents such a strip. The ends of each bend are soldered to that end of the strip which is intended to form the outside connection. Each strip is provided with a series of hemispherical depressions D, serving to receive the active material and at the same time to hold the bends of the strip in their respective lateral positions. Rods C, C, resting in sockets C' above and below, are provided to hold the strips in their proper position. The electrodes are arranged side by side, each consisting of one strip.

*Storage-Battery Plate.* Edward H. Winkes, Buffalo, N. Y. Patent No. 711,917, October 21, 1902. Application filed April 25, 1902.

This patent also relates to an improved form of battery plates, and embodies exactly the same idea as the preceding



STORAGE-BATTERY PLATE.

plate, in so far as a battery plate is made from a single sheet of lead bent in serpentine form, and both inventors propose to keep the folds of the plate separate by hemispherical depressions, as illustrated in the preceding patent. The main difference is that the former inventor bends a thin *strip* or ribbon into serpentine form lengthwise, whereas this one proposes to corrugate a *sheet* of lead sidewise, as it were, so closely that the corrugations are one-thirty-second to one-sixteenth of an inch apart. As the electrolyte could not directly get from one side of the plate to the other in this arrangement, a number of horizontal cuts are made in the plate, through which the circulation can take place. The inventor of the present construction provides a better support for his plates than the one of the preceding patent by mounting them in a bifurcated frame of antimonial lead and soldering the various folds to that frame. He also provides a larger number of the hemispherical depressions, intended to keep the folds separated, and, moreover, roughens the sheets before folding them, and thus furnishes a more suitable seating surface for the active material.

*Electric Accumulator.* F. Loppé, H. P. Morin, G. J. Griner and D. P. Martin, Paris, France. Patent No. 712,316, October 28, 1902. Application filed October 26, 1899.

In order to obtain a plate combining lightness with large capacity, the inventors construct the electrodes of a number of thin rectangular sheets of lead. Each of these sheets is undulated and perforated with a large number of small holes, forming conical projections, distributed over both faces of the plates. The appearance of the surface is compared to that of a nutmeg grater. A number of these sheets are arranged parallel to each other, and are then folded closely. Space is thus provided between them for the filling in with active material. The coating can either be done by pasting the active material on the sheets at the time the folds are made, or by forming them electrolytically, according to the Planté system. Separators of any insoluble substance are placed between the different electrodes of a cell.

*Secondary Battery.* Robert Welford, Sunderland, England. Patent No. 713,189, November 11, 1902. Application filed November 21, 1899.

This invention refers to the construction of a battery plate, said to be applicable to the cells of the Planté type, as well as those of the Faure type. In the case of the Faure-type cell, the inventor uses a conducting wire coiled into a helix, and surrounded by active material in such a manner that a wire constitutes the core of a rod or prism of active material. "Thus," says the inventor, "if we imagine a number of candles hanging from a horizontal rod, we obtain a good conception of an elementary form of this invention, it being borne in mind that the tallow corresponds with the paste and that the conductor, coiled or folded, corresponds with the wick." In order to keep these rods apart, a corrugated sheet of hard rubber is employed. The battery plate is constructed by laying a helix of lead wire first on one side into one of the corrugations of the hard rubber plate, then passing it underneath and up on the other side, twisting the free ends of the wire together on top of the plate. The candles of active material are now prepared by taking a quantity of paste and working it well in and behind the lead wires. If the plate is to be one of the Planté type, he uses an increased quantity of lead wire, coiled, wound or folded into more or less compact form, or places one coil of lead wire into the other. The inventor apparently did not bother about the circulation of the electrolyte.

*Storage Battery.* Bruce Ford, Philadelphia, Pa. Patent No. 712,999, November 4, 1902. Application filed August 28, 1902.

The battery plate described is provided with strips along each side, these being bent into tubular leads or flanges, which impart the requisite stiffness to the plate, and are also useful as a guide in the application of the active material. Wires may be inserted in the flanges at the corners for the purpose of strengthening them.

*Non Active Metal for Use in Storage Batteries.* H. H. Lloyd, Germantown, Pa. Patent No. 713,568, November 11, 1902. Application filed June 29, 1900.

This invention relates to a process of treating antimonial lead, containing about 12 per cent. of antimony, in such a manner that it can be made a suitable material for use in storage

batteries. Antimonial lead has heretofore been used, but the material was brittle, not flexible or resilient, and comparatively heavy in proportion to its mechanical strength, so that it could not be obtained in sheets thin enough for many purposes. The inventor claims to have discovered that such material, after having been cast, can be materially changed in its characteristics by subjecting it to repeated cold rolling or equivalent forging. The effect of the cold rolling upon the cast antimonial lead is to remove it from the class of brittle metals to the class of metals of which sheets of hard rolled copper are a good example. It is stated that the material thus prepared possesses the mechanical strength which is lacking in pure lead, resists the action of acid better than pure lead and cast antimonial lead and is much lighter than either for the same strength.

*Supporting and Lifting Mechanism for Secondary Battery Plates.* L. H. Flanders, Wilkinsburg, Pa. Patent No. 711,488, October 21, 1902. Application filed February 24, 1902.

The invention relates to means for supporting the electrodes of secondary batteries in the tanks, and for lifting the plates from the tanks for cleaning or repairs. The plates are provided on each side with a projecting lug, resting upon a bar or beam of plate glass or other insulating material, which in their turn find their support in recesses provided at each corner of the receptacle. The lifting is done by simple mechanical means.

*Separator for Storage-Battery Plates.* Rufus N. Chamberlain, Depew, N. Y. Patent No. 712,178, October 28, 1902. Application filed May 13, 1901.

The specification describes a new form of separator, which also prevents short circuits at the edges of the plates, caused by the dropping off of active material. It consists of a flat, perforated plate of hard rubber or other impervious material, which is provided with flanges along its upright edges. Each positive electrode is inclosed by a pair of separators, the side flanges of the separators inclosing the upright side edges of the electrode. The separators are further provided with spring ribs or projections, bearing against the electrodes and serving to keep the separators a little distance away from them.

*Battery Installation for Submarine Boats.* S. Lake, Bridgeport, Conn. Patent No. 712,814, November 4, 1902. Application filed March 3, 1902.

This invention has for its object to provide a storage battery installation system for submarine boats, which shall be compact, shall insure a thorough insulation between the several battery cells and their permanent relative disposition within the hull, and shall effectually prevent the escape of the battery fumes and gases into the adjacent portions of the boat. To this end, the inventor uses a special construction of air and gas-tight compartment for inclosing the system of storage battery cells, and a composite water proof insulating lining for this compartment, a water-proof and non conducting cement filling intermediate the several battery cells and the side walls. The construction is described in detail.

*Process of Forming Electric Accumulators.* W. Morrison, Chicago, Ill. Patent No. 711,997, October 28, 1902. Application filed March 18, 1901.

The specification describes an electrolytic process for the rapid disintegration of storage-battery plates, preparatory to their formation. The electrolyte proposed is hydrofluoric acid, or any of the soluble fluorides in a solution containing any of the chlorates, nitrates or similar compounds of a highly oxydizing nature capable of acting with the fluorides. Non-oxydizing agents, as acetic acid, may also be successfully used in solution with a soluble fluoride and a suitable "exciter." When the hydrofluoric acid or other soluble fluoride is placed in a solution containing nitrates, chlorates or a combination of them or similar compounds, by which fluorine gas is liberated by the action of the electric current and in combination with the other gases, the fluorine and other gases will attack the plate, producing a disintegrated material, strongly adhering to its support and throughout its mass. This material is afterward to be converted into an oxide of lead or spongy lead. If the fluorides are not used in the electrolyte, this mass will not possess the highly desirable adhesive qualities described. Special stress is laid on the assertion that nitrates, chlorates, etc., in solution with sulphuric acid, etc., do not produce sufficiently cohesive material for practical purposes. The plates to be treated are introduced into an electrolyte, as described, and used as anodes; lead plates being used as cathodes. Afterwards the plates are placed in a solution of sulphuric acid and water. It is said that, in order to hasten the process, this solution may contain zinc or any other metal capable of being deposited on the plate. This is supposed to be dissolved by the sulphuric acid and to produce nascent hydrogen, whereby spongy lead is produced on the plate. It is stated that other reducing agents, as which are named tartaric and oxalic acids, can be added to the solution in order to assist the reduction and to more completely reduce the disintegrated structure to spongy lead in a shorter time.

*Process of Peroxydizing Storage-Battery Plates.* R. N. Chamberlain, Depew, N. Y. Patent No. 712,995, November 4, 1902. Application filed August 23, 1900.

The invention refers to an improvement on the process of peroxydizing storage-battery plates. According to the inventor, the solution used up to now as an electrolyte consisted of sulphuric acid, to which a certain proportion of alkaline nitrates or a small amount of nitric acid were added. The first method is said to leave a certain amount of soluble alkaline sulphates in the bath, which are apt to lead to injurious secondary reactions; while the second method is said to have the disadvantage that the nitric acid, not being set free in the bath in a nascent state, is not as energetic as it would be if it were nascent. It is proposed to remedy these defects by adding to the sulphuric acid solution a suitable proportion of the nitrate of a metal whose sulphate is substantially insoluble in the bath—for example, nitrate of lead. The plates are first placed in a pickling solution, composed of dilute nitric acid, and are then transferred to a bath containing a solution of sulphuric acid, of 36.7 parts of $H_2SO_4$ to every 100 parts of water. To this are added 16 parts of nitrate of lead. The plates to be peroxydized are connected as anodes in this bath, preferably before the addition of the nitrate of lead. Upon electrolysis, lead nitrate is formed at the anode, which is immediately converted into sulphate, adhering to the anode. This is gradually converted by the oxygen into peroxide of lead. On addition of lead nitrate to the solution, lead sulphate is, of course, precipitated, and new nitrate of lead is added from time to time to maintain the efficiency of the bath. The precipitated sulphate which accumulates in the bath, is removed from time to time. After the plates have received a sufficient coating of peroxide, they are taken out of the bath, washed and put in the ordinary forming bath, where they are electrolyzed till all the sulphate of lead remaining on them has been cleaned off.

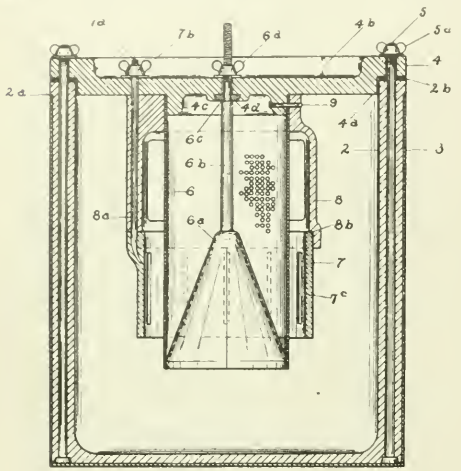
## GALVANIC CELLS.

*Gravity Battery.* W. N. Gore, Philadelphia, Pa. Patent No. 712,008, November 4, 1902. Application filed January 10, 1902.

The invention applies particularly to gravity cells like the ordinary crow-foot cell, and consists in replacing the copper electrode used in this type of cells by one composed of Babbitt metal. The inventor claims that by this substitution the strength of the battery is materially increased, and that one cell containing Babbitt metal as one of the electrodes is equal in strength to two cells in which copper is used in series. The e. m. f. of the crow foot cell is about .98 volt, and the cell under consideration is stated to have an e. m. f. of 1.2 volts. Claim No. 1 covers broadly the use of Babbitt metal as an element of any battery.

*Voltaic Cell.* Herbert B. Taylor, Newark, N. J. Patent No. 713,174. November 11, 1902. Application filed April 2, 1902.

The specification describes a new form of battery of the zinc copperoxide type, belonging to the class of water tight cells, and primarily designed for use on boats or automobiles.




ZINC-COPPEROXIDE CELL.

Its construction can be seen from the accompanying figure. Here 2 represents the jar, preferably of hard fibre, covered on the outside with a metal jacket 3. From the cover is suspended a separator or insulator 8, of the same material as the jar and cover, serving to support the positive zinc electrode. There is also suspended from the cover a so-called "container" 6, preferably of perforated metal. The bottom of the container is formed by the negative electrode 6a, of copper, in the shape of a cone, on which rests the material used as a depolarizer, small cakes or pellets of cupric oxide being preferably used in this instance. It will be seen from the figure that the cell can be quickly taken apart and repaired if necessary.

*Electric Battery.* Albert J. Cook, Jersey City, N. J. Patent No. 710,953. October 14, 1902. Application filed July 20, 1901.

The specification describes at length a new form of cell, constructed with a view of obtaining as large an electrode surface for a given space as possible, and facilitating charging and repairs. One electrode is made in one piece of rectangular cross section, and divided into four compartments, each being of triangular shape. Porous cups, also of triangular shape, are inserted into these compartments and the opposite electrodes, four in number, and also of triangular shape, are introduced into the porous cups. A system of ribs on the bottom of the containing vessel, into which the various parts fit, serve to keep them in position. The cover is made fluid-tight. The cell is evidently designed for use on automobiles.

*Tank.* Hugh Bradshaw, Chicago, Ill. Patent No. 711,465. October 21, 1902. Application filed June 13, 1902.

The invention "relates to a form of tank adapted to be sunk into the ground for the purpose of inclosing and protecting various devices from freezing." For example, in railway signaling systems it is the practice to employ batteries for operating the various devices of the system, and it is highly desirable that these batteries be protected against weather attacks, and particularly against freezing. A tank is shown in the specification, embodying several devices to prevent cold air from getting into the interior.

MISCELLANEOUS.

*Process of Framing Glass or other Materials.* H. W. Scattergood, Philadelphia, Pa. Patent No. 709,513. September 23, 1902. Application filed June 19, 1902.

The process consists in sticking the various pieces of glass, arranged in the desired design, on a sheet of thin paper, leaving uniform spaces between the respective pieces. This is then transferred to a board, a frame of wood is put around it and the spaces are filled with starch or cream of tartar, after which the whole is covered with sand to the top of the mold. Another board is then put on top, clamped to the first, and the object is reversed. The first board is then removed, the paper stripped off and the starch or other material in the spaces metallized by the application of metal powder. Another frame is then put on top of the first one; the back of the object, with the exposed metallization, is painted over with fluid wax or any other adhesive, and the whole second frame is then filled with molten wax, which will solidify and form a backing for the object during the remainder of the process. The frames are then removed, the sand cleaned off and the starch filling in the spaces taken out, thus leaving the design, with the metallized spaces between, in such shape that it can be put into the electrolytic bath. The metallization of the spaces constitutes the cathodes, upon which the metal is deposited.

## THE ELECTRICITY BUILDING OF THE UNIVERSAL EXPOSITION OF ST. LOUIS, U. S. A., 1904.

The Electricity Building of the Universal Exposition of St. Louis, 1904, is the largest ever provided, by an exposition or otherwise, for electrical exhibits and displays. It covers virtually 300,000 square feet of ground space, as against 250,000 covered by the Electricity Building at the Columbian Exposition, at Chicago, in 1893, and 75,000 by the Electricity Building at the Pan-American, at Buffalo, in 1901. It is of most graceful design and proportions, forming an elaborate pentagon, each of its five sides presenting a succession of splendid columns after the richest Corinthian order, four sides being surrounded by a balcony of rare grace and beauty. It incloses an open central circular court, surrounded by rich colonnades, which will be banked with masses of flowers and make a pleasing retreat for visitors to the building.

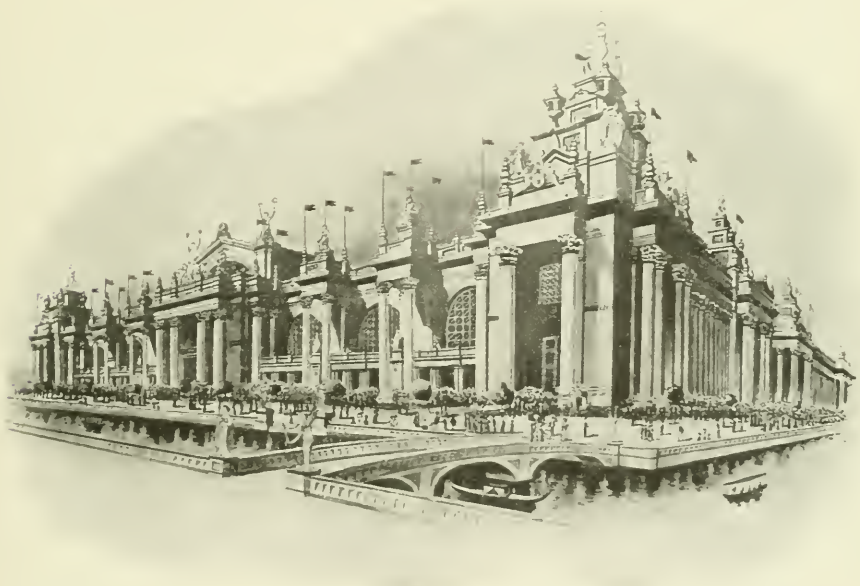
Its location within the exposition grounds is most favorable. It rises right at the foot of the grand terrace and cascades, and thus constitutes a prominent feature of the main arrangement of the rich section, which is called the main picture of the exposition. The eastern exposure of the building fronts 525 feet on the main avenue of the exposition. This broad thoroughfare leads up from the main entrance to the grand basin and cascades, and is penetrated by the central lagoon. The southern exposure, facing the grand basin and the cascades, is in direct view of the electric fountains, the peristyle of the Festival Hall and the splendid Fine Arts palaces. On the west and north the building is bordered by other principal avenues of the exposition and additional extended arms of the lagoon. It is therefore completely surrounded by water. It is led up to by splendid arch bridges, which will discharge the crowds into the broad avenues directly surrounding the building. Four main entrances are provided, one imposing portal at the meeting of the two north facades and one at the center of each of the other sides. Graceful and ample entrances are also provided at the corners of the building. The doors are of gigantic dimensions, 11 x 18 feet. The north facades of the building measure 600 feet, which makes its greater dimensions 525 x 600 feet; 176 trusses and 185 tons of steel have been used in its construction.

The details of the building are well executed in every respect. The fenestration is bold, liberal and appropriate, giving ample light, while affording substantial wall treatment. On two sides graceful and capacious loggias have been extended, which enhance the general beauty of the facades, offering pleasing

effects of light and shadow. A rare scheme of indirect illumination is being worked out, and will be applied to the building, which will accentuate its beauty at night.

The design of the building and its general and special proportions and arrangement are peculiarly adapted for an effective display of exhibits. There are numerous openings in the facades, such as exhibitors seek in selecting their exhibit spaces. Each of the 300,000 feet of floor space is directly available. It is all ground-floor space, there being not a foot of gallery space in the building, nor in any other exhibit building of the exposition, a feature of the Electricity Building and of the Universal Exposition that will be welcomed and appreciated by exhibitors and public alike.

A great traveling crane, to be used in the placing of the heavy electrical machinery which is to be exhibited, will be installed in the building, and all other conveniences afforded to exhibitors in locating and placing their exhibits.



ELECTRICITY BUILDING, SAINT LOUIS EXPOSITION.

In the Electricity Building, those electrochemical exhibits will be placed which show electrochemical processes in operation. This is in agreement with the general idea of the director of the electrical department of the exhibition, Prof. W. E. Goldsborough, to make the Electricity Building not a museum of finished products, but to make it full of life, to show how the products are made and how the processes are being worked. In this way it is hoped that the Electricity Building will become extremely attractive to the general public, who wish to see "something doing," and it is to be hoped that the electrochemical manufacturers will use this opportunity to win the interest and good-will of the general public by exhibiting model plants.

ERRATUM.—In our November issue, page 102, second column, line 13 from the bottom, there is a typographical error. The sentence should read: "Hydrogen (in combination) has always one positive bond." In the numerical applications in the same article this rule is correctly applied throughout, so that we trust our readers have already corrected the misprint.

## LOW TEMPERATURE RESEARCHES.*

BY JAMES DEWAR,

*President of the British Association for the Advancement of Science*

[*Concluded from page 91*]

The strong condensing powers of liquid hydrogen afford a simple means of producing vacua of very high tenuity. When one end of a sealed tube containing ordinary air is placed for a short time in the liquid, the contained air accumulates as a solid at the bottom, while the higher part is almost entirely deprived of particles of gas. So perfect is the vacuum thus formed that the electric discharge can be made to pass only with the greatest difficulty. Another important application of liquid air, liquid hydrogen, etc., is as analytic agents. Thus, if a gaseous mixture be cooled by means of liquid oxygen, only those constituents will be left in the gaseous state which are less condensable than oxygen. Similarly, if this gaseous residue be in its turn cooled in liquid hydrogen, a still further separation will be effected, everything that is less volatile than hydrogen being condensed to a liquid or solid. By proceeding in this fashion, it has been found possible to isolate helium from a mixture in which it is present to the extent of only one part in 1,000. By the evaporation of solid hydrogen under the air pump we can reach within 13 or 14 degrees of the zero, but there or thereabouts our progress is barred. This gap of 13 degrees might seem at first sight insignificant in comparison with the hundreds that have already been conquered. But to win one degree low down the scale is quite a different matter from doing so at higher temperatures. In fact, to annihilate these few remaining degrees would be a far greater achievement than any so far accomplished in low temperature research.

For the difficulty is two fold, having to do partly with process and partly with material. The application of the methods used

* Presidential Address, to the British Association for the Advancement of Science. On account of lack of space the chapter on the upper air and auroras, in the latter part of the address, had to be omitted. Otherwise the address is printed nearly in full.—Ed.)

in the liquefaction of gases becomes continually harder and more troublesome as the working temperature is reduced. Thus, to pass from liquid air to liquid hydrogen—a difference of 60 degrees—is, from a thermodynamic point of view, as difficult as to bridge the gap of 150 degrees that separates liquid chlorine and liquid air. By the use of a new liquid gas exceeding hydrogen in volatility to the same extent as hydrogen does nitrogen, the investigator might get to within 5 degrees of the zero. But even a second hypothetical substance, again exceeding the first one in volatility to an equal extent, would not suffice to bring him quite to the point of his ambition. That the zero will ever be reached by man is extremely improbable.

A thermometer introduced into regions outside the uttermost confines of the earth's temperature might approach the absolute zero, provided that its parts were highly transparent to all kinds of radiation, otherwise it would be affected by the radiation of the sun, and would therefore become heated. But supposing all difficulties to be overcome, and the experimenter to be able to reach within a few degrees of the zero, it is by no means certain that he would find the near approach of the death of matter sometimes pictured. Any forecast of the phenomena that would be seen must be based on the assumption that there is continuity between the processes studied at attainable temperatures and those which take place at still lower ones. Is such an assumption justified? It is true that many changes in the properties of substances have been found to vary steadily with the degree of cold to which they are exposed. But it would be rash to take for granted that the changes which have been traced in explored regions continue to the same extent and in the same direction as those which are as yet unexplored. Of such a breakdown low-temperature research has already yielded a direct proof, at least in one case. A series of experiments with pure metals showed that their electrical resistance gradually decreases as they are cooled to lower and lower temperatures, in such ratio that it appeared probable that at the zero of absolute temperature they would have no resistance at all and would become perfect conductors of electricity. This was the inference that seemed justifiable by observations taken at depths of cold which can be obtained by means of liquid air and less powerful refrigerants. But with the advent of the more powerful refrigerant, liquid hydrogen, it became necessary to revise that conclusion. A discrepancy was first observed when a platinum resistance thermometer was used to ascertain the temperature of that liquid boiling under atmospheric and reduced pressure. All known liquids, when forced to evaporate quickly, by being placed in the exhausted receiver of an air pump, undergo a reduction in temperature, but when hydrogen was treated in this way it appeared to be an exception. The resistance thermometer showed no such reduction as was expected, and it became a question whether it was the hydrogen or the thermometer that was behaving abnormally. Ultimately, by the adoption of other thermometrical appliances, the temperature of the hydrogen was proved to be lowered by exhaustion, as theory indicated. Hence, it was the platinum thermometer which had broken down. In other words, the electrical resistance of the metal employed in its construction was not, at temperatures about *minus* 250° C., decreased by cold in the same proportion as at temperatures about *minus* 200°. This being the case, there is no longer any reason to suppose that at the absolute zero platinum would become a perfect conductor of electricity; and in view of the similarity between the behavior of platinum and that of other pure metals in respect of temperature and conductivity, the presumption is that the same is true of them also. At any rate, the knowledge, that in the case of at least one property of matter we have succeeded in attaining a depth of cold sufficient to bring about unexpected change in the law expressing the variation of that property with temperature, is sufficient to show the necessity for extreme caution in extending our inferences regarding the properties of matter near the zero of temperature. Lord Kelvin evidently anticipates the possibility of more remarkable electrical properties being met with in the metals near the zero. A theoretical investigation on the relation of "electrions" and atoms has led him to suggest a hypothetical metal having the following remarkable properties: Below 1 degree absolute it is a perfect insulator of electricity; at 2 degrees it shows noticeable conductivity, and at 6 degrees it possesses high conductivity. It may safely be predicted that liquid hydrogen will be the means by which many obscure problems of physics and chemistry will ultimately be solved, so that the liquefaction of the last of the old permanent gases is as pregnant now with future consequences of great scientific moment, as was the liquefaction of chlorine in the early years of the last century.

The next step towards the absolute zero is to find another gas more volatile than hydrogen, and that we possess in the gas occurring in clevite, identified by Ramsay as helium, a gas which is widely distributed, like hydrogen, in the sun, stars and nebulæ. A specimen of this gas was subjected by Olszewski to liquid air temperatures, combined with compression and subsequent expansion, following the Cailletet method, and resulted in his being unable to discover any appearance of liquefaction, even in the form of mist. His experiments led him to infer that the boiling point of the substance is probably below 9 degrees absolute. After Lord Rayleigh had found a new source of helium in the gases which are derived from the Bath springs, and liquid hydrogen became available as a cooling agent, a specimen of helium cooled in liquid hydrogen showed the formation of fluid, but this turned out to be owing to the presence of an unknown admixture of other gases. As a matter of fact, a year before the date of this experiment I had recorded indications of the presence of unknown gases in the spectrum of helium derived from this source. When subsequently such condensable constituents were removed, the purified helium showed no signs of liquefaction, even when compressed to 80 atmospheres, while the tube containing it was surrounded with solid hydrogen. Further, on suddenly expanding, no instantaneous mist appeared. Thus helium was definitely proved to be a much more volatile substance than hydrogen, in either the liquid or solid condition. The inference to be drawn from the adiabatic expansion effected under the circumstances is that helium must have touched a temperature of from 9 to 10 degrees for a short time without showing any signs of liquefaction, and consequently that the critical point must be still lower. This would force us to anticipate that the boiling point of the liquid will be about 5 degrees absolute, or liquid helium will be four times more volatile than liquid hydrogen, just as liquid hydrogen is four times more volatile than liquid air. Although the liquefaction of the gas is a problem for the future, this does not prevent us from safely anticipating some of the properties of the fluid body. It would be twice as dense as liquid hydrogen, with a critical pressure of only 4 or 5 atmospheres. The liquid would possess a very feeble surface tension, and its compressibility and expansibility would be about four times that of liquid hydrogen, while the heat required to vaporize the molecule would be about one-fourth that of liquid hydrogen. Heating the liquid 1 degree above its boiling point would raise the pressure by 1¾ atmospheres, which is more than four times the increment for liquid hydrogen. The liquid would be only 17 times denser than its vapor, whereas liquid hydrogen is 65 times denser than the gas it gives off. Only some 3 or 4 degrees would separate the critical temperature from the boiling point and the melting point, whereas in liquid hydrogen the separation is respectively 10 and 15 degrees. As the liquid refractivities for oxygen, nitrogen and hydrogen are closely proportional to the gaseous values, and as Lord Rayleigh has shown that helium has only one-fourth the refractivity of hydrogen, although it is twice as dense, we must infer that the refractivity of liquid helium would also be about one-fourth that of liquid hydrogen. Now, hydrogen has the smallest refractivity of any known liquid, and yet liquid helium will have only about one-fourth of this value—comparable, in fact, with liquid hydrogen just below its

critical point. This means that the liquid will be quite exceptional in its optical properties, and very difficult to see. This may be the explanation of why no mist has been seen on its adiabatic expansion from the lowest temperatures. Taking all these remarkable properties of the liquid into consideration, one is afraid to predict that we are at present able to cope with the difficulties involved in its production and collection. Provided the critical point is, however, not below 8 degrees absolute, then from the knowledge of the conditions that are successful in producing a change of state in hydrogen through the use of liquid air, we may safely predict that helium can be liquefied by following similar methods. If, however, the critical point is as low as 6 degrees absolute, then it would be almost hopeless to anticipate success by adopting the process that works so well with hydrogen. The present anticipation is that the gas will succumb after being subjected to this process, only, instead of liquid air under exhaustion being used as the primary cooling agent, liquid hydrogen evaporating under similar circumstances must be employed. In this case the resulting liquid would require to be collected in a vacuum vessel, the outer walls of which are immersed in liquid hydrogen. The practical difficulties and the cost of the operation will be very great, but, on the other hand, the descent to a temperature within 5 degrees of the zero would open out new vistas of scientific inquiry, which would add immensely to our knowledge of the properties of matter. To command in our laboratories a temperature which would be equivalent to that which a comet might reach at an infinite distance from the sun would indeed be a great triumph for science. If the present Royal Institution attack on helium should fail, then we must ultimately succeed by adopting a process based on the mechanical production of cold through the performance of external work. When a turbine can be worked by compressed helium, the whole of the mechanism and circuits being kept surrounded by liquid hydrogen, then we need hardly doubt that the liquefaction will be effected. In all probability gases other than helium will be discovered of greater volatility than hydrogen. It was at the British Association meeting in 1896 that I made the first suggestion of the probable existence of an unknown element which would be found to fill up the gap between argon and helium, and this anticipation was soon taken up by others and ultimately confirmed. Later, in the Bakerian Lecture for 1901, I was led to infer that another member of the helium group might exist having the atomic weight about 2, and this would give us a gas still more volatile, with which the absolute zero might be still more nearly approached. It is to be hoped that some such element or elements may yet be isolated and identified as coronium or nebulium. If amongst the unknown gases possessing a very low critical point some have a high critical pressure, instead of a low one, which ordinary experience would lead us to anticipate, then such difficultly liquefiable gases would produce fluids having different physical properties from any of those with which we are acquainted. Again, gases may exist having smaller atomic weights and densities than hydrogen, yet all such gases must, according to our present views of the gaseous state, be capable of liquefaction before the zero of temperature is reached. The chemists of the future will find ample scope for investigation within the apparently limited range of temperature which separates solid hydrogen from the zero. Indeed, great as is the sentimental interest attached to the liquefaction of these refractory gases, the importance of the achievement lies rather in the fact that it opens out new fields of research and enormously widens the horizon of physical science, enabling the natural philosopher to study the properties and behavior of matter under entirely novel conditions. This department of inquiry is as yet only in its infancy, but speedy and extensive developments may be looked for, since within recent years several special cryogenic laboratories have been established for the prosecution of such researches, and a liquid air plant is becoming a common adjunct to the equipment of the ordinary laboratory.

VARIOUS LOW-TEMPERATURE RESEARCHES.

We may now summarize some of the results which have already been attained by low-temperature studies. In the first place, the great majority of chemical interactions are entirely suspended, but an element of such exceptional powers of combination as fluorine is still active at the temperature of liquid air. Whether solid fluorine and liquid hydrogen would interact, no one can at present say. Bodies naturally become denser, but even a highly expansive substance, like ice, does not appear to reach the density of water at the lowest temperature. This is confirmatory of the view that the particles of matter under such conditions are not packed in the closest possible way. The force of cohesion is greatly increased at low temperatures, as is shown by the additional stress required to rupture metallic wires. This fact is of interest in connection with two conflicting theories of matter. Lord Kelvin's view is that the forces that hold together the particles of bodies may be accounted for without assuming any other agency than gravitation or any other law than the Newtonian. An opposite view is that the phenomena of the aggregation of molecules depend upon the molecular vibration as a physical cause. Hence, at the zero of absolute temperature, this vibrating energy being in complete abeyance, the phenomena of cohesion should cease to exist, and matter generally be reduced to an incoherent heap of cosmic dust. This second view receives no support from experiment.

The photographic action of light is diminished at the temperature of liquid air to about 20 per cent. of its ordinary efficiency, and at the still lower temperature of liquid hydrogen only about 10 per cent. of the original sensitivity remains. At the temperature of liquid air or liquid hydrogen, a large range of organic bodies, and many inorganic ones, acquire under exposure to violet light the property of phosphorescence. Such bodies glow faintly so long as they are kept cold, but become exceedingly brilliant during the period when the temperature is rising. Even solid air is a phosphorescent body. All the alkaline earth sulphides which phosphoresce brilliantly at the ordinary temperature lose this property when cooled, to be revived on heating; but such bodies in the first instance may be stimulated through the absorption of light at the lowest temperatures. Radio-active bodies, on the other hand, like radium, which are naturally self-luminous, maintain this luminosity unimpaired at the very lowest temperatures, and are still capable of inducing phosphorescence in bodies like the platino-cyanides. Some crystals become for a time self-luminous when cooled in liquid air or hydrogen, owing to the induced electric stimulation causing discharges between the crystal molecules. This phenomenon is very pronounced with nitrate of uranium and some platino-cyanides.

In conjunction with Professor Fleming, a long series of experiments were made on the electric and magnetic properties of bodies at low temperatures. The subjects that have been under investigation may be classified as follows: "The Thermo-Electric Powers of Pure Metals," "The Magnetic Properties of Iron and Steel," "Dielectric Constants," "The Magnetic and Electric Constants of Liquid Oxygen," "Magnetic Susceptibility."

The investigations have shown that electric conductivity in pure metals varies almost inversely as the absolute temperature down to *minus* 200 degrees, but that this law is greatly affected by the presence of the most minute amount of impurity. Hence the results amount to a proof that electric resistance in pure metals is closely dependent upon the molecular or atomic motion which gives rise to temperature, and that the process by which the energy constituting what is called an electric current is dissipated essentially depends upon non homogeneity of structure and upon the absolute temperature of the material. It might be inferred that at the zero of absolute temperature resistance would vanish altogether, and all pure metals become perfect conductors of electricity. This conclusion, however, has been rendered very doubtful by

subsequent observations made at still lower temperatures, which appear to point to an ultimate finite resistance. Thus the temperature at which copper was assumed to have no resistance was *minus* 223 degrees, but that metal has been cooled to *minus* 253 degrees without getting rid of all resistance. The reduction in resistance of some of the metals at the boiling point of hydrogen is very remarkable. Thus copper has only 1 per cent., gold and platinum 3 per cent. and silver 4 per cent. of the resistance they possessed at zero C., but iron still retains 12 per cent. of its initial resistance. In the case of alloys and impure metals, cold brings about a much smaller decrease in resistivity, and in the case of carbon and insulators like gutta percha, glass, ebonite, etc., their resistivity steadily increases. The enormous increase in resistance of bismuth, when transversely magnetized and cooled, was also discovered in the course of these experiments. The study of dielectric constants at low temperatures has resulted in the discovery of some interesting facts. A fundamental deduction from Maxwell's theory is that the square of the refractive index of a body should be the same number as its dielectric constant. So far, however, from this being the case generally, the exceptions are far more numerous than the coincidences. It has been shown in the case of many substances, such as ice and glass, that an increase in the frequency of the alternating electromotive force results in a reduction of the dielectric constant to a value more consistent with Maxwell's law. By experiments upon many substances, it is shown that even a moderate increase of frequency brings the large dielectric constant to values quite near to that required by Maxwell's law. It was thus shown that low temperature has the same effect as high frequency in annulling the abnormal dielectric values. The exact measurement of the dielectric constant of liquid oxygen, as well as its magnetic permeability, combined with the optical determination of the refractive index, showed that liquid oxygen strictly obeys Maxwell's electro-optic law even at very low electric frequencies. In magnetic work the result of greatest value is the proof that magnetic susceptibility varies inversely as the absolute temperature. This shows that the magnetization of paramagnetic bodies is an affair of orientation of molecules, and it suggests that at the absolute zero all the feebly paramagnetic bodies will be strongly magnetic. The diamagnetism of bismuth was found to be increased at low temperatures. The magnetic moment of a steel magnet is temporarily increased by cooling in liquid air, but the increase seems to have reached a limit, because on further cooling to the temperature of liquid hydrogen hardly any further change was observed. The study of the thermo-electric relations of the metals at low temperatures resulted in a great extension of the well known Tait thermo-electric diagram. Tait found that the thermo-electric power of the metals could be expressed by a linear function of the absolute temperature, but at the extreme range of temperature now under consideration this law was found not to hold generally; and, further, it appeared that many abrupt electric changes take place, which originate probably from specific molecular changes occurring in the metal. The thermo-electric neutral points of certain metals, such as lead and gold, which are located about or below the boiling point of hydrogen, have been found to be a convenient means of defining specific temperatures in this exceptional part of the scale.

The effect of cold upon the life of living organisms is a matter of great intrinsic interest, as well as of wide theoretical importance. Experiment indicates that moderately high temperatures are much more fatal, at least to the lower forms of life, than are exceedingly low ones. Professor McKendrick froze for an hour at a temperature of 182° C. samples of meat, milk, etc., in sealed tubes; when these were opened, after being kept at blood heat for a few days, their contents were found to be quite putrid. More recently some more elaborate tests were carried out at the Jenner Institute of Preventive Medicine on a series of typical bacteria. These were exposed to the temperature of liquid air for twenty hours, but their vitality was not affected, their functional activities remained unimpaired, and the cultures which they yielded were normal in every respect. The same result was obtained when liquid hydrogen was substituted for air. A similar persistence of life in seeds has been demonstrated even at the lowest temperatures; they were frozen for over a hundred hours in liquid air, at the instance of Messrs. Brown and Escombe, with no other result than to affect their protoplasm with a certain inertness, from which it recovered with warmth. Subsequently commercial samples of barley, pea, vegetable marrow and mustard seeds were literally steeped for six hours in liquid hydrogen at the Royal Institution, yet when they were sown by Sir W. T. Thiselton Dyer at Kew, in the ordinary way, the proportion in which germination occurred was no less than in the other batches of the same seeds which had suffered no abnormal treatment. Bacteria are minute vegetable cells, the standard of measurement for which is the "mikron." Yet it has been found possible to completely triturate these microscopic cells when the operation is carried out at the temperature of liquid air, the cells then being frozen into hard, breakable masses. The typhoid organism has been treated in this way, and the cell plasma obtained for the purpose of studying its toxic and immunizing properties. It would hardly have been anticipated that liquid air should find such immediate application in biological research. A research by Professor Macfadyen, just concluded, has shown that many varieties of micro-organisms can be exposed to the temperature of liquid air for a period of six months without any appreciable loss of vitality, although at such a temperature the ordinary chemical processes of the cell must cease. At such a temperature the cells cannot be said to be either alive or dead, in the ordinary acceptation of these words. It is a new and hitherto unobtained condition of living matter—a third state. A final instance of the application of the above methods may be given. Certain species of bacteria during the course of their vital processes are capable of emitting light. If, however, the cells be broken up at the temperature of liquid air, and the crushed contents brought to the ordinary temperature, the luminosity function is found to have disappeared. This points to the luminosity not being due to the action of a ferment—a "Lucierase"—but as being essentially bound up with the vital processes of the cells, and dependent for its production on the intact organization of the cell. These attempts to study by frigorific methods the physiology of the cell have already yielded valuable and encouraging results, and it is to be hoped that this line of investigation will continue to be vigorously prosecuted at the Jenner Institute.

And now, to conclude my address, I may remind you that I commenced by referring to the plaint of Elizabethan science, that cold was not a natural available product. In the course of a long struggle with nature, man, by the application of intelligent and steady industry, has acquired a control over this agency which enables him to produce it at will, and with almost any degree of intensity short of a limit defined by the very nature of things. But the success in working what appears at first sight to be a quarry of research that would soon suffer exhaustion has only brought him to the threshold of new labyrinths, the entanglements of which frustrate, with a seemingly invulnerable complexity, the hopes of further progress. In a legitimate sense, all genuine scientific workers feel that they are "the inheritors of unfilled renown." The battlefields of science are the centers of a perpetual warfare, in which there is no hope of final victory, although partial conquest is ever triumphantly encouraging the continuance of the disciplined and strenuous attack on the seemingly impregnable fortress of nature.

To serve in the scientific army, to have shown some initiative and to be rewarded by the consciousness that in the eyes of his comrades he bears the accredited accolade of successful endeavor is enough to satisfy the legitimate ambition of every earnest student of nature.

## ELECTRIC PROCESS OF STEEL MANUFACTURE.

The electrometallurgy of iron and steel is at present exciting great interest. Mr. Marcus Ruthenberg's very interesting paper, read at the Niagara Falls meeting (this journal, page 84), elicited a long and animated discussion (this journal, page 58). Some information on results obtained in actual practice in Sweden and Italy were given in Mr. Carl Hering's synopsis (this journal, pages 70 and 71).

With regard to the plant in Gysinge, Sweden, a consular report of Mr. Robert S. S. Bergh, of Gothenburg, contains the following translation from a recent issue of the *Trading and Shipping Journal* of that city:

"At the meeting of the Iron Manufacturers' Association (Bruksocieteten) at Jernkontoret, Engineer F. A. Kjellin and Mr. Benedicks gave some very interesting information about the production of electro-steel at Gysinge.

"The problem of smelting steel by electricity has for a long time attracted the attention of inventors, and experiments have been made here. By the advice of Engineer Kjellin, Mr. Benedicks decided in 1899 to build at Gysinge an electric steel furnace 'without electrodes.'

"In the latter part of February, 1900, the first furnace was finished and ready for trial, and, after a few experiments, the first ingot was produced. The steel was found to be of excellent quality. The problem was thus solved technically, but not economically, for, with the dynamo of 78 kilowatts used, not more than 270 kilograms (575 pounds) of steel were obtained in twenty-four hours, and in the furnace there was not room for more than 80 kilograms (176 pounds). A larger furnace was seen to be necessary, and this was completed in November, 1900, and proved to be a great improvement. In the second furnace, which held 180 kilograms (397 pounds), from 600 to 700 kilograms (1,322 to 1,543 pounds) of steel were produced in twenty-four hours. The Gysinge sulphite factory burned down on August 11, 1901, and it was decided to build steel works in its place and to use the water power available there. For the steel furnace there was utilized a turbine of 300 horse-power, with direct-coupled generator. The new furnace is to hold 1,800 kilograms (3,970 pounds), and the production is estimated to be at least 1,500 tons a year if charged with cold raw material.

"Engineer Kjellin said that the steel produced is of superior quality and characterized by strength, density, uniformity, toughness and the ease with which it can be worked in cold, unhardened condition, even when containing a very high percentage of carbon. Compared with other steel, it also has less tendency to crack or warp when hardened.

"The reason why this steel in certain qualities differs from other steel, especially in its softness when unhardened, is considered to be its freedom from gases. The manufacture of special steel, with nickel, chrome, manganese or wolfram, will, of course, not meet with any difficulties. The chrome steel and wolfrom steel produced at Gysinge have proved to be excellent for lathe tool. When used for permanent magnets, the Gysinge wolfram steel has been found to give stronger magnets than any other wolfram steel, and has not warped in the hardening.

"From estimates made, it has been ascertained that the furnace used at Gysinge, which is simple in construction and easily managed, has prospects of competing, as to cost of operation, with the furnaces heretofore used for fusion of steel, especially as it yields steel of a better quality.

"For this country (Sweden), with its good ores and large supply of water power, the electric method of smelting steel ought to be of great importance, and abroad, where blast furnace gas is becoming a cheap source of power, it ought to come into extensive use.

"After the lecture Engineer Wahlberg made some statements concerning tests of steel ingots from Gysinge, which had been found to be uniform and homogenous. Microscopic examinations had indicated that there was no difference between the electro steel and crucible steel, which was so much more remarkable, as the electro steel in other respects had different qualities."

## REDISCOVERY OF A PROCESS FOR RENDERING PHOSPHORIC ACID AVAILABLE.

By Prof. Charles Baskerville.

In endeavoring to secure a mechanical method for concentrating phosphatic pebble, found in the coastal plain region of North Carolina (Castle Haynes Mines), the concentric structure of many of the nodules was redetermined (Penrose, U. S. Geological Survey, Bulletin 40, 77). A number of analyses of carefully selected pebbles were made, and in no case, except with the fossil teeth, which occur in the deposit to a greater or less extent, could samples be had which contained less than 15 to 20 per cent. each of silica and limestone.

The chemical methods for increasing the content of phosphate were unsuccessful from an economic point of view. Jigged material could be had, which contained from 35 to 44 per cent. of tri-calcium phosphate; so methods of fusing with substances like the alkaline, sulphates, sulphides, nitrates, and finally carbonates, were tried. The last was thoroughly successful, the nitrates giving the largest percentage of citrate soluble phosphoric acid, but the expensive nitrogen was driven off. Knoop (Bied. Centr.—B, 28,576) heated phosphates, bones, etc., with the alkaline silicates, and obtained a 99 per cent. yield of "available phosphoric acid." (U. S. patent, 691,089 (1898).

G. A. Liebig secured the American rights for a process the same as the author's, having preceded him by a few months. The process is of value in those countries where chamber acid is expensive (Sweden) and large deposits similar to the North Carolina carbonaceous and siliceous phosphates are found, as recently noted in Japan (*Science*, x, 900).

## CURRENT NOTES.

The Nobel prize for physics has been awarded to Professors Lorenz and Zeeman, the two distinguished Dutch physicists, who have taken active part in the development of the modern theory of electrons. In the subject of chemistry, the Nobel prize was awarded to Dr. Emil Fischer, who, as successor of A. W. von Hoffman, now occupies the chair of organic chemistry at the University of Berlin. Dr. J. H. van't Hoff, who occupies the chair of physical chemistry at the same university, received the Nobel prize last year. The amount of each prize is $41,600.

At the annual convention of the American Roentgen Ray Society, recently held in Chicago, Prof W. E. Goldsborough, chief of the department of electricity of the Saint Louis Exposition, made an address in which he outlined the plans of his department to bring together a thoroughly representative and advanced exhibit of Roentgen ray and electro-therapeutic apparatus. The convention passed a resolution extending assurances of its cordial support. Prof. W. E. Goldsborough also addressed the Interstate Independent Telephone Association at the recent convention in Chicago and a resolution was passed commending the Saint Louis World's Fair to the support of the independent manufacturers of telephone appliances and supplies.

The president of the Exposition Co. of the Saint Louis Exposition has just announced the organization of world's congresses, to be held in Saint Louis during 1904. Howard J. Rogers, chief of the department of education, is to be the director of congresses. The Advisory Board, to work in conjunction with him, is as follows: Chairman, Nicholas Murray Butler, president of Columbia University, New York City;

* Abstract of a paper read before the Society of Chemical Industry.

William R. Harper, president of the University of Chicago; R. H. Jesse, president of the University of Missouri; Henry S. Pritchett, president of the Massachusetts Institute of Technology, and Herbert B. Putnam, librarian of Congress. The duties of this Advisory Board will be more exacting than usually falls to the lot of advisory bodies. Upon their recommendations will be determined the number and extent of congresses, the emphasis to be placed on special features, the prominent men invited to participate, the character of the programme and the methods for successfully carrying out the enterprise. No effort will be spared to give the series of congresses at this exposition unity and connected purpose, and make their published proceedings a valuable contribution to the world's literature. A series of congresses has been an accompaniment of all recent international expositions, but they have always been disconnected and rather incident to the exposition than related to it and supplementary to the exhibits. The work of the director and Advisory Board will be wholly given to constructing a co ordinate department of the exposition, which shall have an established scientific value and attract the attention of the practical scholars and experts of the world to Saint Louis.

The Lousiana Purchase Exposition, in St. Louis, 1904, will have light effects that have not been exploited even in spectacular theatres. Chief Henry Rustin, of the electrical and mechanical department, is now conducting experiments to this end. The Nernst lamp is among those that are being tried. Other experiments are being made with the Cooper-Hewitt mercury vapor lamp, made by the Sawyer-Man Co., of New York. With this an initial pressure of between 50,000 and 75,000 volts is needed to start the light; then a pressure of only 120 volts suffices to maintain its luminosity. It is a livid phosphorescence, which imparts a ghostly pallor to objects surrounding, daylight colors being completely metamorphosed. Experiments are being made with other vapors than that of mercury, and with lamps of other patterns. It is desired to use in the cascades some phosphorescent light which will not only be luminous itself, but impart luminosity to the water it permeates. It is thought that the required agent has been found in the Geisler tube adaptation, with which experiments are now being made. These long tubes can easily be installed in the lips of the cascade ledges, and the light coming through the falling, turbulent water is expected to produce entirely unprecedented spectacular effects.

Dr. J. A. Holmes, chief of the mines and metallurgy department of the St. Louis Exposition, recently returned to St. Louis, after having been away about a month. He reports that the people of the Atlantic States now take a great deal more interest in the World's Fair than they did when he was in the East several months ago. Many of the manufacturers, who at that time were not disposed to exhibit at the fair, now announce that they desire to exhibit, and some of them have applied for space. At Pittsburg he arranged for a number of iron, steel, coal and coke exhibits, and at Philadelphia for several aluminum and iron exhibits. At New York he secured promises of exhibits illustrating different metallurgical processes in copper, lead and zinc; also exhibits in mining machinery. In Washington, D. C., he conferred with some of the Government officials in regard to exhibits illustrating ore deposits and the extent and distribution of mineral deposits in the United States. In Vermont he arranged for exhibits of slate, granite and marble.

The twenty-fifth anniversary of the Engineers' Club of Philadelphia was recently celebrated by a banquet. The guests included representatives from the national engineering societies, a large number of engineering clubs, as well as the Union League and Art Clubs of Philadelphia and the University of Pennsylvania. Among the distinguished guests were Admiral Melville and the venerable John Fritz.

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

By Carl Hering.

## INDUSTRIAL ELECTROCHEMISTRY.

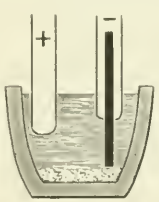
*Bleaching.*—The subject of bleaching powders and liquids is a matter which at present is becoming somewhat important, owing to the overproduction of bleaching powder as a by-product in the electrolytic alkali industry. During the past month several articles of interest in this direction have been published, one of which is on what seems to be a very simple method of producing hydrochlorite of soda for use in place of bleaching powder. The liquid must be made where it is used, but has a number of advantages which still further affect the bleaching-powder industry. The description of this cell of Walker will be found in *Eng. and Min. Jour.*, November 22d. He describes a cell devised by Atkins, of London, which consists of a semi-cylindrical wooden vat, with a horizontal axis, 10 feet long and 2 feet wide. The inside is lined with sheet lead, on which are placed carbon bricks about 2 inches thick, whose inner surfaces form a semi-cylinder concentric with the lead and wood, and act as anode; these carbon bricks are cemented together and to the lead by a water-proof carbon cement. A wooden cylinder covered with lead revolves as the cathode in the vat, within an inch of the surface of the carbons, and the solution of salt fills up the space between. The total area of the anode surface is about 20 square feet. The current used varies from 1,000 to 1,500 ampères at from 3 to 4 volts, and the amount of 10 per cent. solution of salt acted on varies from 500 to 1,000 gallons per hour, according to the strength of the resulting solution of hypochlorite that is required. While hydrogen is given off at the revolving cathode, the solution consists finally of NaClO and some unaffected salt. Owing to the great surface of the electrodes, there is very little resistance, so that the electrolyte hardly becomes heated at all, and thus no other reactions occur and no chlorates are produced. Preferably, the apparatus is worked at the bleaching plant, where the solution is at once used in the bleaching vats, as it is not practicable to store and ship the hypochlorite. No other chemical is required in the bleaching vat, as the hypochlorite rapidly gives off its oxygen when it comes in contact with the pulp or textile fabric and passes back to common salt again. One of the great advantages over bleaching powder is that no insoluble precipitate is formed. For this reason, and because chlorine has been too strong for this purpose, it has been impossible to use bleaching powder in whitening high-class linen. At the present time all the best linens of Ireland are sun-bleached. A large Scotch linen company are now trying the use of hypochlorite. A brief reference is made to the fact that the addition of sulphuric acid to the hypochlorite solution releases chlorine and oxygen, and forms sulphate of soda. It is said to be probable that this would be a better source of chlorine for chlorination than bleaching powders, and at any mine where fuel, water and salt are obtainable such cells might be erected for the direct production and use of chlorine, both in treating gold ores and in leaching low-grade copper ores.

A description of another apparatus for producing bleaching liquids is given in the *Electrochem. Zeit.* for October, its chief advantages being cheapness of the product and simplicity. The apparatus may be compared with a staircase, each step representing a self-contained electrolysis. The salt solution flows down these stairs from step to step, while on each step the electric current flows through it from one side to the other. The plates of every step contain 22 slots each, in which there are imbedded "peculiarly formed bodies of platinum-iridium." The action of the new apparatus is said to be based primarily upon the fact that the salt solution is divided into thin liquid threads, and thus is subjected to the action of the current. Moreover, "the platinum-iridium bodies are so formed that the electrically polarized surfaces are not of equal size, as in all other electrolyses, but the electrode polarized by chlorine has a surface several times as large as the electrode polarized by hydrogen."

The financial state of affairs concerning the bleaching powder industry in England is discussed in an editorial note in the London *Elec.*, November 14th, which was prompted by the failure of the convention held by the English and foreign producers of heavy chemicals, which may be fraught with serious consequences for those of the new electrochemical works which depend upon bleaching powder for their profits. During the past four years bleaching powder has been maintained at an average price of $30 per ton by somewhat artificial means, and the electrolytic alkali works in this and other countries have benefited by the business arrangement existing between the English United Alkali Co., as representing the old Le Blanc process, and the Chemische Fabrik "Elektron," which is the German firm controlling nine tenths of the electrolytic production on the continent. Under this arrangement the latter firm were allowed to dispose of 6,000 tons of bleaching powder per year in the United Kingdom, and the immediate cause of the rupture is said to have been a request that this quantity should be increased to 8,000 tons. Whether this explanation be correct or not, the fact remains that there was a failure of the agreement between the rival producers, and contracts have been signed for the delivery of large quantities of bleaching powder in 1903 at the low price of $20 per ton, delivered at the consumers' works. Should the value of bleaching powder fall to $17.50 a ton, as some believe it may, the margin for profit in this product would be practically wiped out, and many of the electrolytic alkali works would find themselves in an unenviable financial position. The one consolation is that the older Le Blanc will also be severely affected by the fall of prices, and their owners will doubtless be prepared, after a short period of open competition, to meet their rivals half way in any proposals for the further regulation of prices.

*Alkali Industry.*—That prolific writer on electrochemical industries, J. B. C. Kershaw, begins another article in London *Elec.*, November 14th, in which he discusses the present condition of the alkali industries, beginning with that in the United Kingdom. This also bears on the subject of the bleaching industry, and on the overproduction of bleaching powder in Germany. The capacity of the Middlewich works of the Electrolytic Alkali Co. will be increased to 250 cells, and it is estimated that the output will then amount to 12,800 tons of bleaching powder and 18,000 tons of soda crystals per year. The Weston Point works of the Castner-Kellner Co. have paid a dividend of 6 per cent. for the last year. Both at Middlewich and at Weston Point the concentration of the alkaline liquors running from the electrolytic cells is carried out by means of multiple-effect evaporators. The total power available at Middlewich and Weston Point for the production of alkalies and chlorine products is now between 5,000 and 6,000 horse power, and when the additions to the Middlewich plant are completed over 7,000 horse-power will be devoted to the electrolytic decomposition of salt in that country. Should the whole of the chlorine liberated from the salt be converted into bleaching powder, the aggregate production of this chemical by the two electrolytic plants will be about 25,000 tons per year. In Germany, the group of electrolytic alkali works under the control of the Griesheim Co. "Elektron," situated at Bitterfeld, Griesheim and Rheinfelden, appear to be working satisfactorily. The new Aussig "bell" process is being operated at one of the Bitterfeld works, and it is probable that in course of time it will be generally adopted by all the works under the control of the Griesheim firm. At the Bitterfeld plant the annual output of caustic potash and bleaching powder is 7,200 and 12,250 tons respectively, and, in addition, considerable amounts of sodium and magnesium are produced. The output of the Rheinfelden plant is 5,800 tons of caustic potash and 10,000 tons of bleaching powder per year. The maximum output of the group of works at Griesheim, Bitterfeld and Rheinfelden is 25,000 tons of caustic potash and 40,000 tons of bleaching powder per year; and the electrolytic works of the Solvay Co., at Osternienberg, add about 5,000 tons to the latter total. The German home demand for bleaching powder is, therefore, more than covered by the output of the electrolytic plants, and the development of the export trade in bleaching powder is essential for the maintenance of the German electrolytic alkali industry. Already in 1900 the total exports amounted to 25,953 tons, while only 308 tons were imported.

*Furnaces.*—In the "Synopsis" of last month the method of Borchers and Stockem, for the production of metallic calcium, was described. This article has apparently brought forth a description of another method of ARNDT, by which he claims that the same result may be obtained with a more simple apparatus, which he describes in *Zeit. f. Electrochemie*, November 13th. He uses an iron crucible, which is coated inside with the material of fire-brick, mixed with water to a creamy consistence; the bottom is also covered with a layer of fluor spar, and the whole is dried in a warm place for twenty-four hours. A carbon rod is used as anode, and a thick iron wire as cathode, which is covered with a porcelain tube to about 4 cm. from its lower end, as shown in the adjoining diagram. To cool the crucible, it was placed on a large iron block. To fuse the calcium chloride, which, freed from its water, was gradually introduced into the crucible, an arc was used between the carbon anode and a carbon rod (not shown in the figure) held in the hand, and also connected to the negative pole, until the current passed through the bath; the current was then held at 20 to 25 ampères. After having beaten the contents of the crucible to pieces, he found metallic calcium in larger well-fused pieces, which could be easily hammered and filed. At fresh surfaces the metal is nearly white, but soon gets a yellow color. The analysis of a piece thus produced showed 99 per cent. of calcium and 1 per cent. of silicon, no iron or aluminum being present.



CALCIUM FURNACE.

DANNEEL continues, in the *Zeit. f. Electrochemie*, September 25th, the description of other processes which have been worked out in the metallurgical laboratory of the Institute of Technology of Aix-la Chapelle. Some notes are given on preliminary experiments of Borchers, which are to be continued on a large scale, for the production of chromium, free from carbon, in the electric furnace, chromic oxide being placed over a mixture of aluminium oxide with the amount of carbon required for the reduction. Experiments of Stockem are also described. He endeavored to produce cerium by electrolysis, the object being to utilize the waste materials of the gas incandescent lamp manufacture. Cerium is best obtained from the fused chlorides, free from water; less favorable results are obtained with the reduction of the oxide. By the Goldschmidt reduction process, cerium could not be obtained. Some experiments by Borchers and Dorsemagen are noticed on the preparation of red lead, or minium, from lead peroxide and lead oxide. Some

notes are also given on nickel refining, the modern "tops and bottoms" process being represented diagrammatically, and some modifications suggested by Borchers and Guenther being noticed. A detailed article by Guenther on this subject is promised in the near future.

*Testing of Alloys.*—Electrochemical methods seem to be gradually replacing former methods for doing various things. Sirks recently described such a method for testing alloys for industrial purposes, which description will be found in the *Proc. Roy. Akad., Amsterdam,* September 27th, a brief extract of which is given in the London *Elec.,* November 14th. Formerly the specimens were polished and exposed to a tempering flame. The different oxidizing action on the various constituents brings out the crystalline structure of the alloy and gives valuable hints concerning its mechanical properties. Instead of tempering, the metals may also be etched in acids, but this method has various disadvantages, owing to gas bubbles and the like. These difficulties have been removed in the electrolytic method of the author. The specimen is made the anode in an electrolytic cell, with copper as a cathode. Direct current at 4 volts is used; the electrolyte is water with six drops of dilute sulphuric acid per 100 cc. In this way the formation of basic metallic deposits is avoided. Since the etchings are much more pronounced in this method than in the simple acid etching, it is not necessary to polish the specimens; smooth filing suffices. It is possible to etch out individual crystals of the alloy, showing a definite and invariable proportion of the constituents. These crystals are the product of a chemical reaction between the constituents which has a profound influence upon the mechanical properties of the alloy.

*Recovery of Tin from Tin-Plate Scrap.*—The *Chem. Industry,* 1902, page 625, publishes a note on a Swedish patent of Bergman, which is abstracted in the *Eng. and Min. Jour.,* November 15th. He introduces the scrap into an iron vessel filled with a solution of caustic alkali, together with a depolarizer, but no copper oxide. Electrical action sets in; the scrap is stripped, and the tin goes into solution as a stannate of the alkali. When a saturated solution is obtained, the tin is precipitated as oxyhydrate by means of a current of carbon dioxide. The precipitate is filtered off, dissolved in acid and the tin is separated out electrically.

*Electrometallurgy.*—A series of articles by Beadle is published in the London *Elec. Rev.,* September 26th, October 10th and 24th and November 14th, on electrometallurgical problems, especially those discussing the methods which have been proposed for producing metals from the ores. The first three articles deal with copper, lead and zinc, but do not seem to give anything new. The last one is on the production of gold and silver.

## THEORETICAL AND EXPERIMENTAL.

*Artificial Diamonds.*—The experimental researches of Moissan, in which he produced true diamonds in the electric furnace, seem to have interested others in similar directions, and it is not at all unlikely that at some time in the no distant future diamonds may be produced artificially so much cheaper than the natural diamonds that much of the interest now lying in their possession may be lost. Ludwig seems to have had greater success than Moissan, at least in producing diamonds of larger size, as he obtained them as large as a pea. His experiments are described in the *Chem. Zeit.,* vol. 25, p. 970, an abstract of which is given in the *Am. Jour. Sc.* for December. His results may be of special interest, as it is his intention to develop the processes so as to manufacture diamonds on a commercial scale. It was shown by Pepys, in 1815, that an iron wire heated to redness in contact with diamond was converted into steel. The present author claims that, under great pressure, in an atmosphere of hydrogen this reaction is reversed, and also that carbon fused in the electric arc in the absence of iron, under the same conditions of pressure, is likewise converted into diamonds. In carrying out the experiments, pressures as high as 3,100 atmospheres were used. A spiral of iron wire was imbedded in powdered retort carbon and heated by an electric current in a highly-compressed atmosphere of hydrogen. In a few moments the resistance, which was slight at first, on account of the conductivity of the carbon, rose to that of the iron spiral. This indicated that the carbon in contact with the spiral had become non-conducting, and careful examination showed that on some of the pieces of carbon were brilliant, minute crystals, possessing the hardness, specific gravity and refraction of the diamond. The greater part of the carbon contained in the iron spiral had also been connected into diamond. The crystals had the characteristic irregular surface shown by the diamonds produced by Moissan by the sudden cooling of molten iron. To produce diamonds without the use of iron, it was found necessary to use much higher temperatures, and actually fuse the carbon under very high pressure. Thus fused, it was shown to be a non-conductor, and hence was considered to be the molten diamond. Under the pressure employed, this fusion took place very easily in the electric arc, and there were thus obtained spherical masses of the size of peas, having great hardness and crystalline structure.

*Electrolysis of Fused Caustic Potash.*—In the *Zeit. f. Electrochem.,* October 23d, Le Blanc and Brode give an account of their experiments, which are in the form of a continuation of their investigations of the electrolysis of fused caustic soda and potash, recently noticed in this Synopsis. In fused caustic potash the ions are K and OH, and the development of hydrogen at the cathode results from the presence of water dissolved in the fused bath. The values of the decomposition voltage are nearly the same as for caustic soda. From their experiments they conclude with positiveness that it is impossible by Castner's process, in the presence of air, to produce metallic potassium (as distinguished from sodium) from pure fused caustic potash on an industrial scale. They think that Castner probably worked only with fused caustic soda. The impossibility of producing metallic potassium by Castner's process is thought to be due to the fact that metallic potassium at that temperature oxidizes very easily.

*Lead as Anode in Sodium Hydroxide Solutions.*—Experimental investigations were recently made by Elbs and Forssell of the behavior of lead as anode in sodium hydroxide solutions and of the electrolysis of sodium hydroxide solutions containing lead oxides. The principal results are as follows: A lead anode dissolves in sodium hydroxide under different conditions, but always as bivalent lead. In the electrolysis of sodium hydroxide solutions, containing lead oxides with an inert anode, the primary electrolytic action at the anode is the discharge of lead oxide and oxygen, while lead peroxide is secondarily formed; hence the amount of peroxide formed per coulomb increases considerably with increasing temperature. Moreover, the speed of formation of the lead peroxide depends greatly on the material of the anode; the discharged anions have mostly the formula $HPbO_2$ (monovalent). Lead peroxide is formed upon a platinum anode at 20° C. at a voltage which is lower by 0.23 volt than that required for the formation of lead oxide and oxygen. Lead peroxide has, like platinum and some other metals, the property to occlude oxygen, and at a certain voltage the pressure of the occluded oxygen is probably the same as on platinum. The formation of lead peroxide and the re-formation of ions of bivalent lead from it in alkaline solution is not a reversible process. The experiments are described in the *Zeit. f. Elektrochemie,* October 2d.

*Electrolysis of Silver Nitrate.*—A note is published in the London *Elec. Eng.,* November 7th, stating that while it is generally said that silver nitrate becomes acid during electrolysis, yet Roger and Watson found that the acidity diminished. The apparent contradiction has been explained recently by Leduc as being due to a difference of the conditions. With platinum electrodes in a sufficiently-concentrated solution, a brown solid, containing a higher oxide of silver, is formed with the

simultaneous formation of nitric acid, which, however, when a sufficient concentration is reached, reacts on the compound with the formation of oxygen. Similar results are obtained with soluble anodes and a sufficient current density, and the acidity of the bath therefore leads to a limiting value. He finds that a corrosion or solution of the cathode deposit does not take place, and the experiments also indicate that in a silver nitrate voltameter the polarization e. m. f. is about 0.03 volt.

*Amalgam Potentials.*—REUTER gives an account in the *Zeit. f. Elektrochemie,* October 16th, of an experimental investigation of the electromotive behavior of potassium amalgams. Haber and Sark previously investigated sodium amalgams, and the present author found that his results correspond with theirs. His principal results are as follows: Potassium amalgams containing very low to high per cents. of potassium were prepared, and their potentials were measured in a solution of 1.50 per cent. $LiCl$ in methyl alcohol. The other electrode was Ostwald's well-known mercury standard electrode. The measurements were made at —80° C. The results are plotted in the form of a curve, which shows a characteristic and large break in continuity at the point corresponding to the alloy $Hg_{12}K$. The potentials have about the position in the curve which they should have according to Berthelot's rule, the heat of formation measuring the change of free energy. The potential of pure potassium and pure sodium is lowered considerably by slight additions of mercury.

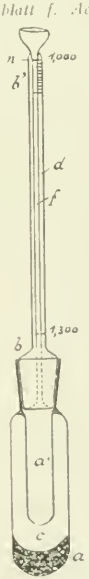
*Reduction by Calcium Carbide.*—As is well known, this material may be used for the reduction of metallic oxides and salts, the action being similar to that of aluminum, but much more powerful. There seems to be some doubt, however, about the formula representing the process, and this is of practical importance, as it shows the quantities required, which may decide whether or not a process becomes practicable. Two papers have recently been published, one by NEUMANN, in the *Zeit. f. Elektrochem.*, October 2d, and another by VON KNEGELGEN, in the same journal, October 9th. Both have investigated its action, but have reached different conclusions concerning the formula. The formula found by the latter requires considerably less carbide for the process, and it therefore appears less hopeless for practical application. The principal difference between the views of the two authors is that Neumann assumes that primarily carbon monoxide is formed, while von Knegelgen assumes the primary formation of carbon dioxide. Neumann has made some gas analytic measurements, and claims that they prove the correctness of this view; von Knegelgen denies that this is proved by those measurements, and promises the publication of a more detailed study of the problem.

*Oxidation Processes.*—BODLAENDER has written a long article, in the form of a contribution to the theory of some technical reduction and oxidation processes. It seems to contain very valuable figures, but cannot be abstracted. It is published in the *Zeit. f. Elektrochemie,* October 30th. At the end of the article the author gives the most important interpolation formulas for the free formation energies, relating to the oxidation of carbon to carbon dioxide, the oxidation of carbon to carbon monoxide, the oxidation of carbon monoxide to dioxide, the formation of carbon monoxide from carbon and carbon dioxide, the combination of hydrogen and oxygen, the oxidation of zinc, the oxidation of iron and the formation of hydrochloric acid from hydrogen and chlorine.

*Maxwell's Theory and Electrolysis.*—In the *Electrochem. Zeit.* for September PLATNER concludes his mathematical article on Maxwell's theory of electricity and its importance in the theory of electrolysis. The electrolyte is compared by him with Maxwell's dielectric medium. The electric force produces in this medium a condition similar to elastic tension (dielectric displacement). There are pressures produced in the medium which result in mechanical motion, there being a tension along the lines of force and a pressure perpendicular to the lines of force. He adds the supposition that the different materials of the electrolyte react in a different manner against these forces, and thus gets what he believes to be a basis which is quite sufficient for the explanation of electrolytic phenomena without the use of any "fantastic hypothesis."

*Chemical Effects of Canal Rays.*—G. C. SCHMIDT recently published an account of an experimental investigation in which he endeavored to find whether positive ions in gases exert an oxidizing action. This might be expected, as the negative electrons in cathode rays are known to have a strong reducing effect, which has been explained by the assumption that the negative electron satisfies a positive valency of the metallic atom, so that this requires a lower valency than before. By an argument based on analogy, it might be expected that canal rays, which are assumed to consist of positive ions associated in some way with neutral atoms, would exert an oxidizing action. The author did not, however, find any well-defined oxidizing action. There is powerful decomposition, but it depends upon the nature of the gas and the compound whether the decomposition results in an oxidation or in a reduction. Solid solutions which show luminescence under cathode rays show the same under canal rays, but it decreases rapidly, owing to the decomposition, which is indicated "by the spectrum of the glow becoming whitish." If the gas in the tube is oxygen, and an oxidizable body is in it, the latter is oxidized. If, on the other hand, the gas is hydrogen, the latter reduces any compound capable of reduction. The most typical reaction for canal rays is the decomposition of sodium compounds; it takes place even when only traces of sodium are present, and is revealed by the D line. The article may be found in the *Ann. d Phys.*, November 11th, and is abstracted in *London Elec.*, November 14th.

*Determining the Specific Gravity of Liquids.*—The *Centralblatt f. Accum.* of November 1st publishes an illustrated description of a new "araeo-pyknometer," devised by RAIKOW, which enables one to easily determine the specific gravity of the same small quantity of a liquid at different temperatures in succession. As will be seen in the adjoining illustration, the instrument consists of two parts, the lower one *a a'* and the upper one *b b'*. The lower one is divided into three portions: the lowest *a* is filled with mercury, the second *c* is empty and the third *a'* contains the liquid the density of which is to be determined. The upper end of the latter forms a neck, into which the upper part of the apparatus is set in like the stopper of the neck of a bottle. This upper part consists of two tubes *d* and *f*, the latter being thin, of a diameter of about 1 mm., and placed in the central part of the tube *d*. The two tubes are fused together at the two ends. The instrument is used as follows: The upper part is taken out, and the portion *a'* is filled with the liquid to be tested so that it reaches somewhat into the neck, then the upper part of the instrument is put into the neck, and the whole instrument is placed into water of the desired temperature. The liquid is then drawn out of the upper funnel until it reaches the mark *n* on the scale, with which the tube *d* is provided. Then the floating capacity of the araeo pyknometer is determined in distilled water in the ordinary way, the specific gravity of the liquid tested being read from the scale. When the specific gravity of a liquid at a certain temperature has been determined, and one wants to find it at another higher temperature, it is only necessary to raise to the desired amount the temperature of the water in which the instrument floats and to again adjust the liquid level in tube *f* exactly to mark the *n*. In case one wants to determine the specific gravity at a lower temperature, one first adds one or



ARAEO-PYKNOMETER.

...ings of the liquid into the funnel and then cools the ...ter to the desired lower temperature, all other operations ...ing as before.

*Physical Chemistry.*—Several papers have recently been published on the application of electrochemical methods to special ...ects in inorganic chemistry: one by Loeb, in *Zeit. f. Elektro...*, October 2d; another by Elbs and Brand, Elbs and ...ammer and Klempert, in *Zeit. f. Elektrochemie*, October ...d; a third by Escherich and Moest in *Zeit. f. Elektro...*, November 6th.

## PRIMARY AND SECONDARY BATTERIES.

*Batteries for Electric Launches.*—The scant literature on batteries during the past month contains an illustrated description by Dreihardt of the electric launches exhibited at the International Self-propelled Boat Exposition, at Wannsee, Berlin, 1902. The number of cells in these boats is generally 40 or 80, in order to be able to charge the battery directly from a 110 or 220-volt station. Occasionally boats with 200 cells have been made for charging from 550-volt stations. The charging is nearly always done with constant voltage and variable current, which enables one to complete the charge more quickly and with less attendance. The largest of the three boats exhibited has a battery of 80 cells, each having 15 positive Planté and 16 negative Faure plates. The capacity is 450 ampere hours for a six-hour discharge. The total weight of the battery is 7,000 kg. The description is given in the *Centralblatt f. Accum.*, November 1st and 15th.

*Explosion in a Storage-Battery Plant.*—There were two accidents recently, of a somewhat serious nature, in some storage-battery plants in Germany, which were due to the explosions of the hydrogen and oxygen produced electrolytically in the batteries and used for soldering purposes, a practice which seems to be becoming common in German accumulator works. A description of these accidents is published by Schoop in the *Elec. Zeit.*, November 6th. He recommends taking care to exclude all organic substances from contact with the oxygen, and to use nothing but water for lubricating the valves; also to take care to keep the receptacles for the oxygen and hydrogen separate from each other, so that no mixture of the gases, by carelessness or otherwise, may take place.

*Storage Batteries at the Dusseldorf Exposition.*—London *Eng'ing*, September 17th, continues the long serial on the chemical and metallurgical industries exhibited at this exhibition. It seems that the electrochemical exhibits were confined to storage batteries, and in the present portion those exhibited by various German firms are described.

## GENERAL AND MISCELLANEOUS.

*Water Power Plants.*—A number of large power plants, ...tended more particularly for electrochemical processes, were described during the past month. Among these there is an illustrated description in *L'Ind. Elec.*, October 10th, of the Clavaux plant of the Société d'Electrochemie. The 5,000 horse-power is available during eight months, while at low-water level the available hydraulic power decreases to 3,000 horse-power. The horizontal axle turbines have a capacity of 550 horse-power, the normal speed being 250 revolutions per minute. There are five 375 kw. direct-current generators direct coupled to the turbine. A small 80 kw. generator furnishes the current for light and for various motors in the plant. Each of the 375 kw. direct-current generators is provided with two independent commutators, each giving 2,500 ampères and 75 volts. Only three generators are at work at present. The purely electrolytic processes are mainly for the production of sodium and peroxide of sodium by the Castner & Hulin method.

Several plants in the Alps are described in the *Elec. Age* for December, forming a third part of a series of articles. The French electrochemical and electrometallurgical industries have their principal centre of activity in the region of the Alps. This article first gives a list of 17 power houses, of together 74,000 horse-power, a large portion producing calcium carbide, besides chlorates, aluminum and sodium. Some notes are also given on the installation of the power houses at Giffre, at Chedde, at Chapareillan, at Pontcharra and on the Arve.

The Sault Ste. Marie power house is described in *Cassier's Mag.* for December, by von Schoen.

*Fused Quartz.*—The very great advantages of the use of quartz in place of glass, namely, its great strength, the fact that it can be heated to about 1,400° C. without changing its shape, and the fact that such vessels can be heated without cracking, make the subject of the production of articles in fused quartz a very attractive one, and one which it seems promises to be developed in the near future by means of the electric furnace. Quartz may be welded, blown and shaped just like fused glass, the only difference apparently being in the fact that a very high temperature is required for its fusion, and, unless well fused, difficulties arise in the production of bubbles in the mass. Heraeus, in Germany, has succeeded in making such apparatus by means of the oxyhydrogen flame; Shenstone has worked in Great Britain with the same flame; Hutton, of Manchester, England, has worked with the arc, as was described in his recent Electrochemical Society paper at Niagara Falls. According to the *Zeit. f. Elektrochem.*, November 13th, another German firm now make such articles commercially, although the price is still rather high and the production of small air bubbles in the mass cannot yet be entirely avoided.

*Removing Hair by Electricity.*—It seems that the electric method of removing hair so that it will not grow again has proved to be the surest, although it is at the same time the slowest, process. It is described in the *Arch. d'Elec. Méd.* for October 15th, in an article by Guilloz, which is abstracted in London *Elec.*, November 14th. The cathode is in the form of a fine needle of platinum, gold or, best of all, steel. It is introduced into the skin alongside of the hair to the bottom of the bulb, and a current of 1 or 2 milliampères is passed for a time varying from twenty to fifty seconds. The action is said to be that of a galvano-cautery, but the account also says that hydrogen is disengaged around the end of the needle and appears as a white foam, and it may therefore be electrolytic. It appears that the destructive action will affect the roots of the hair, even though the needle may not be in actual contact.

*Electrolysis and Physiology.*—Berthelot, in *Comptes Rendus*, September 29th, gives an account of an investigation of certain voltaic cells whose behavior has an important bearing upon the physiological action of the animal cells composing the human body. He studied more especially the very small chemical transformation accomplished in a single animal cell during the impact of a single blood wave. An abstract is given in the London *Elec.*, October 31st.

*Standardization of Methods of Chemical Analysis.*—Blount, in a paper in London *Eng'ing*, November 7th, draws attention to the growing demand for standardization. While necessary for such quantities as weights, money, etc., the desirability of standardization is less incontestable for wire and sheet gauges, screw threads, etc., debatable for the dimensions of rails and rolled joists and doubtful for the testing of materials used in construction. Passing to the standardization of chemical analysis, he draws a distinction between the provision for standard samples of steel and the establishment of standard methods of analysis. The discordance of views held by chemists on standard methods is, to some degree, due to want of mutual understanding. The arbitrary methods in use for the examination of water, milk, oils, foods, manures, etc., should be standardized, but true analytical processes, such as the determination of all elements and most inorganic and many organic bodies, cannot be. Standard methods for the determination of a chemical entity cannot be imposed upon trained chemists. Yet he advocates conferences of specialists in dif-

ferent branches of analysis for the discussion of methods, though not for the promulgation of rules. The agitation for standard methods has arisen in a great measure from the occurrence of discrepancies in analysis, due to bad sampling and unskilled work, which cannot be remedied by standardization. With good sampling and skillful work, uniform results will be obtained, irrespective of uniformity of methods. The chemist, he thinks, should be better trained and better paid.

*Dusseldorf Exposition.*—DANNEEL continues his illustrated serial on the electrochemical exhibits in the *Zeit. f. Elektrochem.*, October 16th and 23d. Several instruments of Hartmann & Braun and electric laboratory furnaces of Heraeus are described and illustrated, and some data are given on power gas installations.

*German Electrochemical Patents.*—Some statistical work of the German Patent Office during the past ten years is given in the *Electrochem. Zeit.* for October.

*Owens College Laboratory.*—The electrochemical laboratory at this college in Manchester, under the direction of R. S. Hutton, is described by WALKER in the *Eng. and Min. Jour.*, November 15th. This is the first laboratory in England for study and research of electrochemistry and electrometallurgy.

*Electrochemical Engineering.*—Under the title of "Elektrochemisch Technik," the *Centralblatt f. Accum.* now publishes a supplement in the form of the repertorium of new articles, papers, patents, etc., on electrochemistry, arranged in alphabetical order.

## *Book Reviews.*

ELECTROCHEMICAL ANALYSIS. By Prof. Edgar F. Smith. Third edition, revised and enlarged. 204 pages, illustrated. Philadelphia: P. Blakiston's Son & Co., 1902. Price, $1.50.

There is probably more accurate and exact information on the general subject of the electrodeposition of metals inside the covers of a treatise on electrochemical analysis than in any other kind of publication. After wandering through the maze of poorly-arranged, uncritical and indefinite information on this subject, such as is found in most works on "electrometallurgy," it is wonderfully refreshing to find exact quantitative data, obtained under test conditions, with all the accuracy of description and operation required by the exigencies of quantitative chemical analysis. To any such wanderers, who may have come to feel perhaps that electrometallurgy is largely a rule-of-thumb trade, a perusal of such a book as this of Professor Smith's is heartily recommended as an anti bilious corrective.

While not so pretentious as Classen's work on the same subject, the work, as a book of instruction, is probably more useful. The author describes many home made devices and laboratory arrangements of his own in such familiar style as causes the difficulties of the subject to vanish, and puts the student at once at his ease; he is being instructed by a practical co-worker. The introductory chapters on the action of the electric current on salts, the definitions of electric current, sources of the current, resistances, measuring instruments, description of laboratory and historical sketch of the subject, are all interestingly written, but in some cases the striving for brevity and conciseness has been at the expense of completeness, and a few more pages on some of these heads would have avoided ambiguity and given the student a more just appreciation of the subject.

In the determination of the separate metals and separation of metals from each other, nearly every page contains the complete data and results of critical tests of the methods described, made by the author or his students. Diagrams of the arrangement of apparatus are supplemented by photographs of the apparatus in actual use, taken by Mr. Taggart, and references to the literature of the subject are abundantly given. In the reviewer's opinion, this part of the book (which is, after all, its essential part) is not equaled by any other publication on electrochemical analysis, and will be of great service to every electrochemist, be he purely scientific or practical.

The author speaks, on page 102, of using a current of "2 ampères *per minute*," a mistake which has been carried over from a former edition, and which ought to be corrected. The author's definitions of *volt* and *ampère* need defining more closely, as in their present state they suggest the predicament of the hero of the "Nonsense Book," whose utmost endeavors to find the difference between a *snark* and a *boojum* resulted only in the information that "a *snark* is a *boojum* and a *boojum* is a *snark*."

MONOGRAPHIEN UEBER ANGEWANDTE ELEKTROCHEMIE. Vol. II. Die Gewinnung des Aluminiums und dessen Bedeutung fur Handel und Industrie. By Adolphe Minet. Translated into German by Dr. Emil Abel, Halle a. S.: Wilhelm Knapp. 129 pages, with 57 illustrations and 15 tables. Price, marks 7.

The present volume is the second one of the series of "Monographs on Applied Electrochemistry," edited by Victor Engelhardt, chief engineer of the Siemens & Halske Co., of Vienna. The author is Adolphe Minet, the inventor of the Minet process, who for a number of years has devoted his attention to the manufacture of aluminum. The book is divided into two parts, the first dealing with the production of the metal, the second with its physical properties, alloys and applications in the arts. In the first part the author takes up, in the order named, the chemical methods, with and without the use of sodium, the electro-thermic and the electrolytic methods. The most interesting part of the book for the electrochemical public is the one which is devoted to a description of Minet's own methods and experiments. These are described at length, and various interesting data are given. It is worthy of note that Minet still clings to the opinion about the reactions taking place in his process, which he expressed in his first patent, in 1887, namely, that aluminum fluoride is primarily decomposed by the current. While he devotes over 20 pages to his own process, he treats the Héroult process, which is a great deal more important than his own, on four pages, and the Hall process, which is at least as important as the Héroult process, is dismissed with about 30 lines and a reprint of half a dozen of schematic patent specification figures, either taken from Mr. Hall's patents or from Borchers' "Electrometallurgie." The description of the other processes, besides these three, is given in condensed form, following in the main the exhaustive treatise of Prof. J. W. Richards on "Aluminium" and Borchers' "Electrometallurgie," and the majority of illustrations given in the latter under the head of aluminum are reproduced. In marked contrast to both of these authors, however, Mr. Minet frequently omits to enumerate the specific references to his sources of information, and merely mentions the names of his authorities. There is also a great discrepancy between the figures of the production of aluminum in the various countries which he gives and those that are given at other places. For instance, he gives as the production in 1900, United States, 1,650 tons; Switzerland, 1,232 tons; France, 800 tons, and England, 500 tons. The production as given in the *Mineral Industry*, Vol. XI, 1902, for 1900 is as follows: United States, 3,243 tons; Switzerland, 2,500 tons; England, 500 tons, and France, 1,500 tons.

Considering the book as a whole, one cannot fail to feel that the expectations which the name of the author on the title page might have given rise to have not been fulfilled. As a textbook, it cannot compare with J. W. Richards' presentation of the subject in his well-known work on "Aluminium." Coming, however, as it does from a man who has had a great deal of experience in the manufacture of the metal, it cannot fail to be of interest to anybody who is familiar with the subject, and, despite its shortcomings is well worth a perusal.

Elementary Chemistry. By F. W. Clarke, Chief Chemist of the United States Geological Survey, and L. M. Dennis, Professor of Inorganic and Analytical Chemistry in Cornell University. New York: American Book Co. 340 pages and 51 illustrations. Price, bound in cloth, $1.10.

In this small volume the distinguished authors present an elementary text-book of chemistry, intended to be used by two classes of readers: First, those to whom chemistry is only one item in a general education, and, secondly, those who intend to take a more advanced course in chemical training. For the first class the book is sufficiently full; for the second class it is intended to serve as a legitimate basis for subsequent higher study. As the authors remark in the preface, "the study of chemistry, apart from its scientific and detailed applications, is a training in the interpretation of evidence, and herein lies its chief merit as an instrument of education." This idea is constantly kept in mind throughout the book. A reasonable number of experiments are described, and each generalization is made to follow the evidence upon which it rests.

The subject is rendered attractive and interesting to the student by constant references to the application of chemical science to human affairs, its utility in modern life, the technical methods of manufacture and the various uses of the substances discussed; 266 pages of the book deal with inorganic chemistry, 58 pages with organic chemistry.

Electrolytic action is very briefly and somewhat vaguely discussed on pages 163 to 167, but more can hardly be expected in an elementary text-book of chemistry. Page 167 contains the statement: "Most bases and most acids contain hydroxyl, OH, and when they unite they do so with evolution of water." According to modern ideas, the characteristic feature of a base is that it contains OH ions, and the characteristic feature of an acid that it contains H ions; in the formation of a neutral salt from an acid and a base, the H ions of the former and the OH ions of the latter combine directly to water.

The methods of electroplating and electrotyping, also the electrorefining of metals and the electrolytic manufacture of aluminum are noticed.

On pages 10 and 11 the term "force" is used in a very indistinct way. The authors speak of the conservation of force, instead of energy. They say that "such things as heat, light, electricity, mechanical power, etc., are called forces." Later on force is used in its correct sense.

## THE PRESENT POSITION OF THE STORAGE-BATTERY INDUSTRY IN GERMANY.*

In the manufacture of storage batteries by the big companies, a tendency has prevailed in recent years to disregard inventions which were enticing from a theoretical point of view, but seemed to be of questionable value for the practice, and the principal aim was to make a cell of a construction as simple as possible. The result has been that the cells made by different firms are so similar that the selling of storage batteries might be called, in the strict sense of the word, a trading in lead. The position of the buying agent has become the most important one.

The raw materials are lead, sulphuric acid and glass. No saving can be accomplished in the purchase of the glass, which represents only a small fraction of the total cost. Sulphuric acid is made in many plants as a by product at so low a cost that the prices differ only slightly. Thus the most important point is to buy the lead cheaply.

About a year and a half ago the price of 100 kilograms (220 pounds) of pure soft lead (purity 99.98 per cent.) was marks 37 ($9.25). To-day the greater firms have made contracts by which they get the lead at a price of marks 21 to 25 ($5.25 to $6.25). The price of the lead has fallen step by step, and it is not impossible that it may even fall further. The American Lead Trust is not likely to change this condition. On the one hand, Australia's and Spain's inexhaustible lead mines are strong competitors, as lead commands cheap freight rates, owing to its use as ballast in steamers. On the other hand, German silver and other mines produce large quantities of relatively very good lead at low prices. Neither will the duty proposed in the new German tariff be of great influence. It may be that the prices will rise slightly. In the next few years the German storage-battery manufacturers may have nothing to fear from the competition of foreign industries, which are still in their infancy. Should the lead price rise again to its former value, the only result would be that the consumer has to pay more.

In the purchase of lead, cash payments are the rule. The electrical energy for forming the plates and the wages for the workingmen also require cash payments, and the firm which promptly pays gets the lowest prices. It is therefore evident that only those storage-battery manufacturers who possess large reserves of floating capital can manufacture with profit. Recently the general manager of a Southern German storage-battery plant of good reputation stated privately that, at the present low prices, the plant sells its batteries with loss.

The development of the German storage-battery industry in recent years has already resulted in failures of several smaller companies, and this development will continue, with a stubborn fight of the surviving firms to the finish, if the leading managers don't prefer to unite. The "Cartell" (syndicate), which had been formed last year, has found a sudden death, as it was founded on a wrong basis. As it is easier to induce three competitors to unite than fifteen or more, the time will be ripe for a syndicate when still more companies will have failed, and the few survivors, after having fought bitterly, will recognize that they are of equal standing. The result will be a trust, and, as long as its members don't disagree, no outsider will be able to succeed in establishing himself in the industry if he has not a capital of several millions.

Better conditions prevail in the sale of automobile storage batteries, but the demand is not great.

* Translated from the *Centralblatt für Accumulatoren-Elemenlen und Accumobilenkunde*, Oct. 15

## AMERICAN AUTOMOBILE BATTERIES.—I.

### THE SPERRY BATTERY.

In the Sperry battery, which is manufactured by the National Battery Co., Buffalo, N. Y., the grid, as shown by Fig. 1, is made of thin, pure sheet lead, which is corrugated horizontally. In the bottom of the hollows, formed by the corrugations, numbers of small trapezoidal holes are punched. The punch also cuts diagonally across the trapezoid, and, instead of making a clean hole, fins are left which project on either side of the plate. The whole plate, when punched, resembles a corrugated grater, except that the fins are longer and triangular in shape. These projections are then spread wider apart, so that a pressure on the plate will cause them to bend down in a direction away from the holes from which the fins project.

The material which is to become active is spread in the form of a powder on both sides of the grid, filling up the corrugations and being in sufficient quantity to make a flat plate of usual thickness after press-welding. The whole is then subjected to pressure—about 1,000 pounds per square inch of surface—which forms it into a solid mass. The material is bound to the grid by being pressed together into a continuous mass, which is on both sides of the grid and is welded through the multitude of small holes, thereby riveting itself in the grid. Additional hold is furnished by the fins, which bend down and are clinched over the active material, and thus retain the material at the surface.

The retention by the fins and riveting under pressure of the powder into a solid mass cannot be successfully accomplished with every form of material to become active, but the material

used in the Sperry battery welds up strongly in the press, and, after the chemical formation, becomes hard like soap-stone. This active material consists of 80 to 85 per cent of finely-divided pure lead, obtained by dissolving a precipitation, to which is added 15 to 20 per cent of lead oxide. These are thoroughly mixed, and to the mass thus formed is added about one-twenty-fifth of a compound of alkaline salts and other ingredients.

The alkaline salts and other ingredients are themselves inert, and their function is twofold:

First. They decompose or dissolve when the plates are subjected to the acid bath, just before being subjected to the electrolytic forming process, leaving numerous minute cells throughout the mass of material upon the plates, which cells permit the electrolyte to thoroughly penetrate the mass of material upon the plates during the time they are subjected to the forming process, and also permit the expansion of this

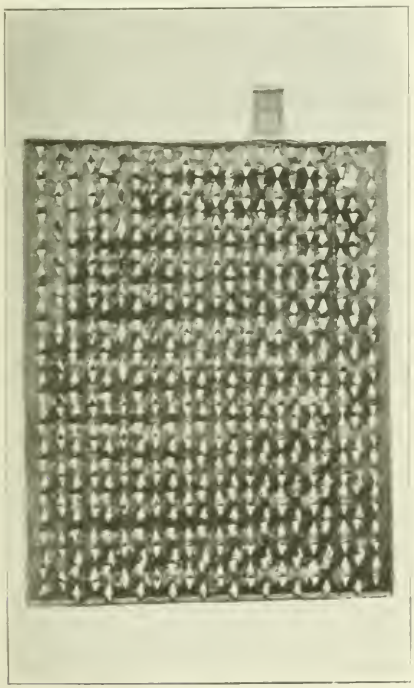


FIG. 1.—GRID, SPERRY BATTERY.

mass of material during the expansion which takes place in the material while the plates are subjected to the forming process, and thereby prevents the active material from crowding off or disintegrating from the grid or support and seriously injuring the plates.

Second. They have the peculiar property of causing the mass of material to harden, not only during the time that the plates are subjected to the forming process, but also during the use of the plates in a storage battery. In other words, this mixture accelerates the forming of the plates by increasing the penetration of the electrolyte, and also prevents serious injury to the plates that otherwise would be caused by the expansion and contraction of the mass of material; and, as above stated, also increases the hardening condition of the mass of material during the use of the plates.

The composition of the active material used, its method of application and the formation of the Sperry battery are such, however, that trouble from disintegration and dropping away of active material is obviated. There are a number of these batteries that have been in use for over two years, and the positive plates are hard, solid and durable.

The corrugation of the grid horizontally allows proper expansion, and relieves the plate of any tendency to buckle. As an additional precaution, however, the Sperry pyroxylin envelope is used, which is applied to the outside of the plate and covers it, passing down one side, under the bottom of the plate, and up the other side. It is evident that if any active material should be loosened by any extraordinary circumstance, it would not be able to drop off the plate, being held in position by the outside coating. If a particle of material should, by any chance, drop off, it is retained in the pyroxylin envelope and will not be able to short circuit the battery.

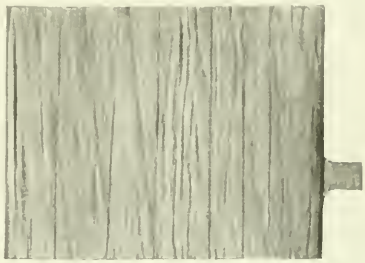


FIG. 2.—PYROXYLIN ENVELOPE.

This covering, or pyroxylin envelope as shown by Fig. 2, is made of open-mesh cotton cloth, such as "cheese cloth," which is chemically treated, forming a cellulose nitrate, which is termed "pyroxylin," and which is of the same general character as gun cotton. The addition of a small quantity of nitrobenzol renders it inert.

The jars in which the elements are placed are of the hard rubber variety, but different from the usual hard rubber jars in that they have a series of ribs, capped with soft rubber, extending across the bottom of the cells. On these soft, resilient ribs rest the plates, which are in this way relieved from excessive shock or jar. The separators are corrugated, perforated, ribbed, hard rubber.

Fig. 3 shows a curve of discharge of the Sperry battery taken from 44 cells in series. These cells weigh 1,005 pound

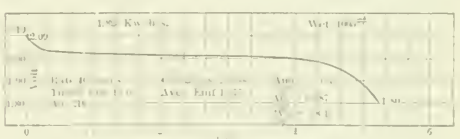


FIG. 3.—SPERRY BATTERY DISCHARGE.

gross, or 23 pounds each. The discharge rate was nearly 40 ampères, and the average voltage 1.975. The curve shows the unusual results of 1.75 ampères, 9.187 ampère hours and 18.15 watt hours per pound gross weight at 5¼-hour discharge, giving, at this rate of discharge, 40 pounds per horse power hour, corresponding to an energy sufficient to raise its own weight against gravity at sea level about 9 miles.

This is equivalent to 2.65 ampères, 7.95 ampere hours, 5.03 watts and 15.09 watt hours per pound at the three hour rate. There are several sizes of these cells manufactured, the principal ones being 2 9-10 x 5½ x 10 inches, and weighing 15 pounds, gross; 2 x 7¼ x 10½ inches, and weighing 18 pounds gross, and 3 x 7¼ x 10½ inches, weighing 23 pounds.

A great number of life tests have been made on this battery, both in laboratories and on vehicles and in practical work.

One vehicle made 7,770 miles with the batteries at a loss of 28 per cent. of the original capacity when the test was discontinued. Several of the Sperry batteries have been in operation actively for over two years, and showed splendid results. The negative plates were apparently as good as when the battery was made, and a test conducted under the general supervision of Prof. John W. Langley, of the Case School of Applied Science, shows that the battery carried through a uniform rate of discharge of 1 ampère per pound until the carriage had run the equivalent of 3,000 miles. This test shows the capacity of the battery for the last ten discharges to be 10 per cent. in excess of the first ten discharges. The battery had not revealed any indication of falling off in capacity, and the forty-fourth discharge of this battery, taking it at 1 ampère per pound of complete working cell, is a mean potential difference throughout the curve of over 2 volts, namely, 2.014, as shown by the following fifteen-minute readings of potential difference and positive and negative cadmiums:

| Time. | Voltage between Plates. | Voltage between Positive Plate and Cadmium. | Voltage between Negative Plate and Cadmium. |
|---|---|---|---|
| 12. | 2.27 | 2.37 | .13 |
| .15 | 2.12 | 2.22 | .13 |
| .30 | 2.12 | 2.22 | .13 |
| .45 | 2.10 | 2.20 | .13 |
| 1. | 2.10 | 2.20 | .13 |
| .15 | 2.10 | 2.20 | .13 |
| .30 | 2.08 | 2.10 | .13 |
| .45 | 2.07 | 2.18 | .13 |
| 2. | 2.05 | 2.16 | .13 |
| .15 | 2.03 | 2.15 | .13 |
| .30 | 2.03 | 2.15 | .13 |
| .45 | 2.03 | 2.15 | .13 |
| 3. | 2.03 | 2.15 | .13 |
| .15 | 2.00 | 2.13 | .13 |
| .30 | 2.00 | 2.12 | .13 |
| .45 | 1.98 | 2.10 | .13 |
| 4. | 1.98 | 2.08 | .13 |
| .15 | 1.97 | 2.07 | .15 |
| .30 | 1.93 | 2.03 | .15 |
| .45 | 1.93 | 2.03 | .15 |
| 5. | 1.90 | 2.03 | .15 |
| .15 | 1.87 | 2.02 | .16 |
| .30 | 1.83 | 2.00 | .17 |
| .45 | 1.80 | 1.97 | .17 |

The company also manufacture a battery for automobile purposes, known as the "National." This battery is a combination of Sperry negative and Planté positive plates. The negative plates are 3-16 inch in thickness, and the positive plates ¼ inch in thickness. The former are made as explained in the description of the Sperry battery. The latter are made from chemically pure sheet lead, rolled to the desired thickness, cut into strips or ribbons and passed through machines of special design, which knurl and weave a straight and corrugated strip alternately. The ribbons are then placed in a form and subjected to hydraulic pressure, fitting them to the frame or grid, which is cast from an alloy of antimony and lead in

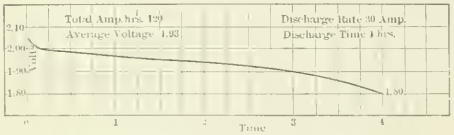



FIG. 4.—SPERRY BATTERY DISCHARGE CURVE.

two pieces. They are next placed in the grid, the center supports and ends of which are burned together, making the plate one piece.

The plates are electrochemically formed by the usual Planté method. Fig. 4 shows the discharge of 24 cells of this battery after 80 discharges, and the battery shows no sign of deterioration. Fig. 5 is the "National" positive plate.

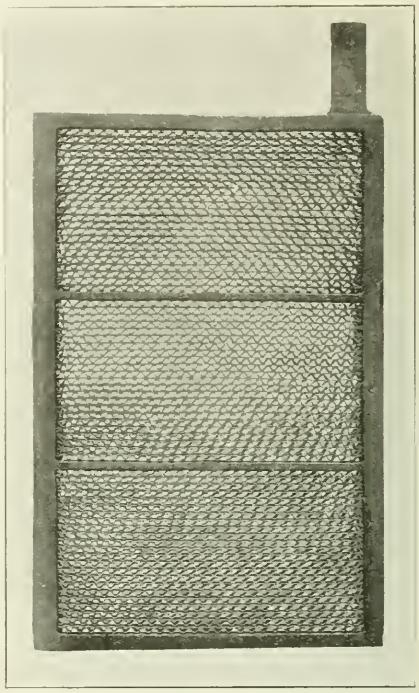


FIG. 5.—NATIONAL POSITIVE PLATE.

The extremely large surface secured by this method of construction makes it possible to obtain the capacity desired with a thin, hard, coherent layer of active material, and permits a free flow of the electrolyte through the plate, allowing it to withstand rapid charging and discharging without serious injury.

### WESTERN STORAGE BATTERY.

The more completely the active material covers the conducting plate or grid, the more enduring is the plate, more especially the positive electrode. For this reason the grid used in the Western storage battery, made by the Western Storage Battery Co. for the National Vehicle Co., Indianapolis, Ind., has a conducting diaphragm of thin, perforated lead running through the center of the plate, just midway between the surface of the outer frame of the plate; then, horizontally across this diaphragm are cast thin lines of lead, the outer edges of which are turned down, so that a slight shoulder is made, under which the oxide paste, to become active, is forced by hand pressure, thus confining the paste against outward pressure, which takes place in the process of forming the positive plates. When the plate is thoroughly pasted, small points of lead only show on the surface. Thus the forming process, in which the electrical current tends to follow the more prominent lead as its easiest line of conduction, is forced to seek the main conductor in the center of the plate, passing through the oxide paste to reach it, and producing the necessary chemical changes on its way. This tends to form the electrodes more evenly. The plates made in this way are light, but stiff, and, being cast of an alloy of lead and antimony, are less rapidly decomposed by the constant action of electrolysis in charging and discharging than soft lead would be. A plate, for example,

of a surface area of 4⅞ x 7¾ weighs 11 ounces, and will hold, when properly pasted, about the same weight of lead oxide paste when dry. Seven of these plates, when formed and charged, have a capacity of 68 to 70 ampere hours when discharged at the high rate of 20 amperes per hour.

In order to give more endurance than is usual in a light battery, the positive electrodes are protected from washing, which the motion of the vehicle gives to the battery electrolyte, by a thin pad of spun glass, made for this purpose. It is held against the two surfaces of the positive plate by perforated hard rubber, on one side of which are several perpendicular ribs, about 1-16 inch thick and ⅛ inch high. This gives free circulation of the liquid and gas along the negative plate, and also holds the very resilient glass pad firmly against the positive plate. The combination of spun glass and hard rubber for separators and insulators has proved an improvement, since there is no chemical action in this material, as there would be in any form of wood or cellulose, which chemical action, set up by electrolysis, is always detrimental to the durability of the lead grid. The following data are the results of a test of a 40-cell battery, each cell weighing 14½ pounds, complete. This battery was made up for the National Vehicle Co., for their road wagon, designated in the list as R 2 battery, and consists of seven plates, three positives and four negatives, the plates having each a surface area of 4⅞ x 7¾ inches. The specific gravity of the electrolyte was 1.250 fully charged, and 1.117 at the end of the discharge:

| Time. | Ampères. | Volts. |
|---|---|---|
| 12. | 20 | 82 |
| 1. | 20 | 81 |
| 1.30 | 20 | 80 |
| 2. | 20 | 79.5 |
| 2.30 | 20 | 78.5 |
| 3. | 20 | 77 |
| 3.30 | 20 | 75 |
| 3.45 | 20 | 68 |

This gives, for a 3¾-hour discharge, 75 ampere hours, with an average power of, approximately, 1,600 watts. At 68 volts the discharge is cut off and recharging at once commenced, since the drop to 68 volts for the series of 40 cells shows 1.6 volts to each cell, which is as low as any battery could be discharged.

The next size of battery, made for stanhope vehicles and park traps, contains the same number of plates, the surface area of which is 5 x 8¼ inches, and the discharge rate is 25 amperes, instead of 20, for 3¾ hours, which gives 94 ampère hours. Forty four of these cells, after making a trip over country roads for three days, of about 65 miles each day, charging in this time three times, made a run of 118 miles the day after charging on the asphalt streets of Indianapolis, taking about eleven hours for the test. In other respects, this battery does not differ outwardly from other batteries in general use.

### SMITH STORAGE BATTERY.

The tray storage battery, invented by Malcom O. Smith, and made by the Smith Storage Battery Co., Binghamton, N. Y., differs in its form widely from the batteries made by other manufacturers, although it involves no new principle. The main new point is that the jars are dispensed with, and the lead plates themselves are used for holding the electrolyte. The gridded plates are formed into oblong trays, with pointed bottoms, the ends also receding from the top to the bottom, so as to permit of nesting.

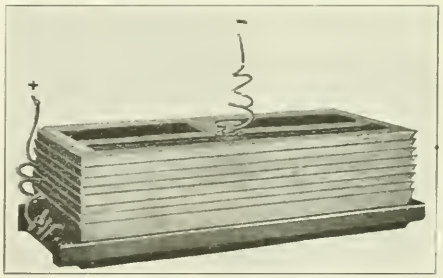
Any desired number of trays can be nested on top of each other, perforated separators of sheets of hard rubber or other suitable material keeping the trays from contact with each other. When nested, there is sufficient space between the trays to hold the electrolyte, which is as much in contact with the bottom of the tray above it as with the under one, which holds it. This permits of an equal chemical action upon the upper surface of one tray and the under side of the one above it.

In preparing the plates, the under side of each tray is chemically treated to become oxide, and the upper side per oxide of lead. This makes the upper side of each tray the positive side, and the under one the negative side, of what in other batteries would be a single cell.

The addition of another tray to the nest is simply the same as adding another cell to an ordinary battery. Of course, the bottom of the lower tray and the inside of the upper one are plain, and are not in contact with the electrolyte. A battery of 11 trays is practically the same as an ordinary one with 10 cells. The voltage of the battery will be twice the number of trays minus one.

One of the battery terminals, the positive, is attached to the bottom side of the bottom tray, and the other, the negative, to the top of the upper one. For the use of the entire battery, there is no connection between the trays except the electrolyte. The use of "jumpers" between the plates, as in ordinary batteries, being unnecessary.

Any combination of series-multiples or multiple series connections can be obtained that are possible with any battery. One terminal can be applied to the top of any tray of the nest, the other to the bottom of any other one. The voltage will always be twice as much as the difference between the number of trays. Between the top of the second tray and the bottom of the fourth one, the e. m. f. is 4 volts; the top of the third and the bottom of the ninth, 12 volts, etc.




SMITH STORAGE BATTERY.

One of the advantages claimed for this type of battery is its extremely low internal resistance. There are no lugs, soldered joints or loose connections, with connecting wires or strips from plate to plate, to offer resistance. At the latter part of a discharge, the current does not have to come from the bottom of the plate through the already discharged upper end. The discharge is practically continuous from the entire surface of every plate.

This results in another advantage, which is the rapid or uneven manner in which it can be discharged without fear of buckling. Inasmuch as the discharge is from the entire surface of all of the plates, it is claimed to make little difference whether it is accomplished in two or three hours or two or three days. Response is made to sudden changes of load with slight variation in voltage. This feature of even response to variable loads is of particular advantage for automobiles, where the demand varies so suddenly.

The form of the battery is claimed to preclude possability of the deposit of active material to form a short circuit between the plates, as frequently happens with jar batteries; such deposits come from the positive plates. In these batteries the positive face of the tray is up, so that there is no tendency for loosening of material; and, should that happen, it simply rests in the bottom of the tray, where it can cause no trouble.

Dispensing with all jars, either of glass or hard rubber, decreases the weight of the battery considerably, and reduces the cost. It is possible to nest an entire battery of any number of cells up to 20 or more.

*[To be continued.]*

## Personal.

Prof. F. Haber sailed for Europe on December 13th. On his extended trip through the United States, he visited nearly all the important electrochemical plants of this country. He intends to publish a report in the *Monographieen fuer Angewandte Elektrochemie*. He expects to issue this report in three or four months. In a recent letter to the president of the American Electrochemical Society, Dr. Haber expresses his sincere thanks for the very amiable reception tendered to him, and extends his hearty wishes for the future welfare of the Society.

## DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

*Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.*

*This digest of electrochemical United States patents prior to July, 1902, will be one by classes, setting out for comparison in each class those devices which have the same object, or those methods which seek the same results. In each class the patents will be arranged chronologically. The digest will be complete in the sense of covering every point which is touched upon in the original specification.*

### DIAPHRAGM CELLS FOR THE PRODUCTION OF CAUSTIC ALKALI.

(*Continued from page 114*)

489,990. October 25, 1892; Henry Blackman, New York, N. Y.

Utilizes difference in specific gravities of brine saturated with chlorine and caustic soda solution, to maintain anode and cathode products of brine separate, by electrolyzing in a centrifugal apparatus, such as a revolving iron drum. Inner surface of drum partially protected by insulating coating, leaving cathode surface at greater distance from axis of drum than are the anodes, which may be arranged in a ring. Separate partitions to direct caustic soda, hydrogen and chlorine to suitable outlets. Central feed pipe for brine. Armature of dynamo to furnish current may be carried on same shaft as centrifugal electrolytic cell.

487,996. December 13, 1892; Thomas Craney, Bay City, Mich.

Closed iron vessel, serving as cathode, containing a number of anode compartments or porous cups. Each cup consists of a number of superposed, loosely interlocking, conical rings of stoneware or glass. A central anode in each cup, also consisting of a series of smaller superposed, conical cups, the space within the cups and the interstices between them being filled with pulverized carbon. Space between anode and porous cup filled with salt crystals, which gradually dissolve and replenish the solution.

488,708. December 27, 1892; Thomas Craney, Bay City, Mich.

Long anode and cathode compartments side by side, partially separated by a depending partition. A layer of sand or asbestos on the bottom of both compartments extends up above lower edge of the partition. A row of anodes, each consisting of a cup filled with pulverized carbon and resting on the sand layer. Connection to the carbon in each cup made by a tube filled with carbon. Cathode compartment divided longitudinally by a series of transverse vertical cathode plates, serving as baffles, causing movement of solution in a vertical zig-zag from end to end. Resistance between each anode and main electrical conductor arranged to increase current supply from inlet to outlet of cell.

489,677. January 10, 1893; James Greenwood, London, Eng.

Vessel of copper, lined with carbon or iron, serving as cathode. Anode, parallel plates of retort carbon, tinned on adjacent faces, with type metal cast between. Diaphragm, superposed V-shaped troughs of porcelain or glass, separated by asbestos or powdered steatite. Upward circulation of brine in both compartments. Anode and cathode solutions may flow through a number of cells in series.

491,700. February 14, 1893; Elisha B. Cutten, New York, N. Y.

Apparatus similar to that of 489,491, except that a porous cup may be substituted for glass anode bell. Upper and lower ends of porous cup glazed. Circulates strong brine upward along anode.

496,863. May 9, 1893; Thomas Craney, Bay City, Mich.

Apparatus similar to that of 487,996. Tank suspended from above and has conical bottom, delivering to a receiver below. Automatic device, controlled by strength of caustic, to regulate outflow from receiver.

496,864. May 9, 1893; Thomas Craney, Bay City, Mich.

Apparatus similar to that of 488,708. Modification shown employing a row of anode bells dipping into a layer of sand, with a cathode between each pair of bells.

496,865. May 9, 1893; Thomas Craney, Bay City, Mich.

Vessel partially divided into anode and cathode compartments by a depending partition. Sand layer on bottom extends up above lower edge of partition. Anode, solid or powdered carbon resting on sand at base of anode compartment. Anode conductor, a tube perforated at its upper end and filled with carbon. Cathode, a loosely-rolled sheet of metal.

498,768, 498,769, 498,770. June 6, 1893; Thomas Craney, Bay City, Mich.

A row of cells similar to that of 496,865, with all the anode and all the cathode compartments connected in series. Cells may be arranged in steps.

498,771. June 6, 1893; Thomas Craney, Bay City, Mich.

Porous cup, consisting of concentric perforated cups, with an intermediate space filled with asbestos. Inner cup filled with granular carbon, serving as anode.

501,121. July 11, 1893; Charles N. Waite, Newton, Mass.

Purifies brine by adding a soluble barium salt, preferably chloride, to remove sulphuric acid existing in combination with calcium, magnesium or sodium.

501,628. July 18, 1893; James Charles Richardson, London, England.

Cathode, a horizontal endless belt of sheet metal, supported on rollers near the bottom of vessel. Terminal brush bears on cathode. Feeds a depolarizer, such as copper oxide, onto one end of the cathode, and delivers the spent depolarizer from the other end into a receptacle, from which it is elevated. Anode bell arranged with its lower edge in contact with layer of depolarizer on cathode.

504,774. September 12, 1893; Thomas Craney, Bay City, Mich.

Separate anode and cathode compartments, connected by an inverted U-tube filled with asbestos. Anode and cathode similar to those of 496,865. Fills cathode compartment with water or weak brine, and displaces caustic by adding fresh water.

505,895. October 3, 1893; Elisha B. Butten, New York, N. Y.

Apparatus similar to that of 489,491 and 491,700. Automatic devices for supplying saturated brine and withdrawing caustic.

507,886. October 31, 1893; Thomas Craney, Bay City, Mich.

Separate, parallel, rectangular anode and cathode compartments of iron. Anode compartment protected by coating of asphalt and an inner lining of cement. A series of inverted U-tubes connect the compartments. End of each U-tube in anode compartment may rest on a pile of asbestos sheets. An air exhaust pipe leads from the bend of each U-tube. Anode, a layer of pulverized carbon resting on bottom of compartment, with a series of connections, each a carbon pencil encased in earthenware or cement. May have an anode compartment along each side of cathode compartment.

[*To be continued.*]

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## ALUMINIUM.

In this issue we publish three articles on the manufacture, the properties and the uses of aluminium. In 1854, Prof. Deville, of Paris, succeeded in obtaining metallic aluminium by electrolyzing the fused double-chloride of aluminium and sodium. In those days, however, electrical energy was expensive, as primary batteries were then the only means of generating an electric current; and Prof. Deville concluded that the electrolytic method could not compete with purely chemical methods. It is amusing to note how completely the situation is now changed, since electrical energy became cheaper and the processes of Hall and Heroult were introduced into practice on a large scale. The article by Dr. J. W. Richards, who has been intimately connected with the development of the aluminium industry, will engage the attention of our readers, as it gives interesting historical notes on the work of Hall and Heroult, together with a discussion of the scientific principles of their process.

Prof. C. F. Burgess and Mr. Carl Hambuechen give an account of valuable laboratory observations on aluminium. To utilize aluminium to greatest advantage, one must be familiar with its particular properties, and especially with its almost ever-present surface coating. The authors show how this coating introduces peculiar difficulties in various processes, like soldering aluminium, plating on aluminium, etc., and they also show the means of overcoming these difficulties. Electroplating upon aluminium should have a great commercial field for certain utensils. On the other hand, the problem of plating with aluminium seems to resolve itself into the problem of finding a suitable solvent which will dissolve an aluminium salt and at the same time will not chemically react with the deposited metallic aluminium. It seems certain that water as a solvent does not do.

The third article in this issue on aluminium is by Mr. G. P. Scholl, on the use of aluminium as a reducing agent in metallurgical processes. That aluminium is a very strong reducing agent has long been known, but there was no use of working out the details of such a process, as long as aluminium itself was expensive. The decrease of the price of aluminium paved the way for Dr. Goldschmidt's important process. In this connection we may note that calcium carbide has similarly been tried as a reducing agent in recent years. These are only special cases of the general rule that electrochemical processes enable us to store up energy in producing chemicals which may afterwards be used as reagent in other processes.

## ON FARADAY'S LAW.

In this issue we print two contributions relating to Faraday's law; a long article by Mr. Carl Hering, and a brief communication by Dr. H. C. Cooper. Dr. Cooper refers to an

article published in our November issue on Faraday's law and the theory of electrons. In this article it was shown that Prof. O. C. Johnson's well known notation of positive and negative bonds may easily be applied to electrochemical calculations, because his positive and negative bonds may be considered to correspond to positive and negative charges. In electrochemical processes the change of valency in Johnson's sense is nothing else but the giving off or receiving of electric charges at the electrodes. Prof. Johnson's old notation may therefore be interpreted as an expression in different words of what is now generally assumed to be the mechanism of the transport of electricity through an electrolyte by means of charged ions.

Dr Cooper appears to consider it preferable for didactic reasons to put the latter mental picture at the head of such considerations. He appears to object to the use of the word bond. But whatever may be thought about bonds and valency in the light of recent investigations, we do not see any possible way to evade the idea of valency in electrochemical action and in the application of Faraday's law. It does not seem possible to describe the chemical action at the electrodes of an electrochemical cell otherwise than as reduction and oxidation (or as Dr. J. W. Richards says, "perduction"), that is, as changes of valencies. Of course, one might use other terms, but we do not see what useful purpose could thereby be accomplished. Even Dr. Cooper, after having expressed himself against the use of the terms bond and valency, uses, in the expression of Faraday's law, the term "equivalent amounts." With the essential contents of Dr. Cooper's explanations we fully agree; in fact, he states the views expressed in our former article on Faraday's law and the theory of electrons, only in different words, by carefully evading the term chemical bond and substituting for it at once the idea of an electric charge. This is in absolute agreement with the sentiment expressed in our former article.

Mr. Carl Hering's article will certainly be extremely welcome to the rapidly increasing number of workers in the electrochemical field. Faraday's law is the foundation of every calculation in electrolytic processes, and a table which simplifies these calculations and saves time is, of course, of great value to the busy practical man. The table is also to be heartily recommended as being the result of a complete and careful recalculation of the electrochemical equivalents, based upon the most recent and best fundamental values; moreover it contains columns relating to the energy, which we believe are not to be found in any other table and which may often be used to advantage in practice.

In the text which accompanies his table, Mr. Hering illustrates the use of his table by a series of typical examples, well chosen, in order to show the great variety of possible cases. This text is, in fact, a concise treatise on Faraday's law, and the student who reads it carefully and recalculates the various examples should be highly benefited. We desire to add a few remarks on the relation between the methods of calculation, described by Mr. Hering and that in which the ionic charge is used as a basis; and some further remarks on the interconnection between the two methods, described by Mr. Hering.

The method of calculation, which is based on the ionic charge, is perhaps the safest for anyone familiar with the idea of charged ions in all but the simplest cases. The method is to first find the equation which represents the complete electrochemical action; this action is necessarily a reduction at the cathode and a "perduction" (or oxidation) at the anode. In the sense of the ionic theory the reduction at the cathode is a loss of positive charges given off to the cathode; monovalent ions (like H) give off one charge; bivalent (like Cu in $CuSO_4$) two charges, etc. The perduction at the anode is a gain of positive charges (or a loss of negative charges); the zinc atom which goes into solution in the Daniell cell is changed from an atom to an ion and thus gains two charges. It is evident that the number of charges received from the anode in any given time must be exactly equal to the number of charges given off to the cathode in that time. When the equation representing the whole reaction has thus been found, and when it has been determined how many charges are received from the anode and given off to the cathode, then one has simply to remember that each such charge represents 96,540 coulombs, if the chemical symbols in the equation represent gram molecules or gram atoms or gram ions. The further calculation is then very simple. There is no essential difference between this method and the method based upon the change of valency in connection with the table, but there is this practical difference: the former method requires some calculations which are avoided by the use of the table.

One point might, however, be emphasized. While the valency is generally considered in text-books to be the determining factor in calculations with reference to Faraday's law, Mr. Hering speaks of the *change of valency*, instead of the valency itself. This is strictly correct, and the ionic theory takes exactly the same view. For instance, if at an inert cathode ferric sulphate is reduced to ferrous sulphate, the change of valency of Fe is from three to two, the difference being one. From the point of view of the ionic theory, a three-valent Fe gram ion has a charge of three times 96,540 coulombs and a bi-valent Fe gram ion has a charge of two times 96,540 coulombs; hence the change from a three-valent to a bi-valent gram ion Fe corresponds to giving off 96,540 coulombs to the cathode.

Finally we will point out the interconnection between the two methods, discussed in Mr. Hering's article. The one consists in taking the change of valency and reading the amount perduced at the anode or reduced at the cathode directly from the table. The other method, which he calls the older chemical method, requires the exact knowledge of the equation representing the total electrochemical action. It is, of course, self-evident that both methods must be essentially one and the same, but there is one point which, at first sight, may appear a puzzle to the student. In "the older chemical method" one must know the co-efficients of the different terms entering into the equation of the electrochemical reaction. In the other method nothing is required but a knowledge of the change of the valency, and Mr. Hering even gives an example to show that the co-efficients in the equation of the reaction may be ignored. It is self-evident that this puzzle can be solved only by proving that there is a distinct relation between

the co-efficients of the equation and the numbers representing the change of valency at both electrodes.

Now this relation is nothing but the old well-known rule given by Prof. O. C. Johnson for balancing an equation which represents a process involving oxidation and reduction. This means that if we know the change of valency of the element reduced at the cathode (for instance, say, three) and the change of valency of the element perduced at the anode (say two), then we know the co-efficients with which these elements enter into the equation representing the total electrochemical reaction. In our special case this co-efficient is two for the former (reduced) element and three for the latter (perduced) element. As was pointed out in the article in our November issue, already referred to above, this rule becomes quite self-evident in the light of the ionic theory. In our special case it means that if the element reduced at the cathode gives off three positive charges to the cathode and the element perduced at the anode receives two positive charges from the anode, then it is necessary that two atoms are reduced at the cathode in the same time as three atoms are perduced at the anode, because only under this condition the same number of positive charges (six in this special case) pass from the anode into the electrolyte as pass from the electrolyte to the cathode.

## PHYSICAL CHEMISTRY AND ELECTROCHEMISTRY.

In a recently published report of the Census Committee of the American Chemical Society, Dr. Louis Kahlenberg discusses the development of modern physical chemistry. He points out that it would be wrong to believe that physical chemistry has sprung up suddenly and has developed from the subjects of chemistry and physics in an unnatural or artificial manner; on the contrary, the very opposite is shown to be the fact, as the beginnings of physical chemistry date back to the very beginnings of chemistry. The founders of modern chemistry, the men that were so prominent during the latter part of the eighteenth and the former part of the nineteenth century, to a very large extent employed physical means to investigate chemical problems. And during the period of the development of analytical and organic chemistry, while attention was primarily directed to the end products of chemical reactions, yet nearly all of the physical means known to-day were used more or less extensively; the balance, the pycnometer, the thermometer, the retort, etc., and even the calorimeter, the spectroscope, the polariscope, the galvanometer, the refractometer and photometer were at times called into requisition.

Dr. Kahlenberg shows how the two sciences of physics and chemistry, at first practically one, became gradually more and more distinct, as the chemists were chiefly occupied in studying the end products of chemical reactions, while the physicists developed refined methods of exact measurement. And yet during this entire period there always were some men whose researches lay on the border line between the two sciences. The work of these men kept alive the intimate connection between chemistry and physics and forms the foundation of modern physical chemistry. Modern physical chemistry is distinguished from the older "pure" chemistry, not by the methods used, but by the object of investigation; the field is a broader one. Not only the end products of chemical action are studied, but also the processes of the formation of these products, together with all the concomitant energy changes that take place. Physical chemistry is thus general chemistry—chemistry of the most general kind. Dr. Kahlenberg concludes his remarks by appealing to physical chemists to bear constantly in mind the general aim of their work, which, like that of all sciences, is to minister to the welfare of mankind in the broadest and highest sense of the word. Science must have all avenues for its progress open; but it must be borne in mind that science is for man and not man for science.

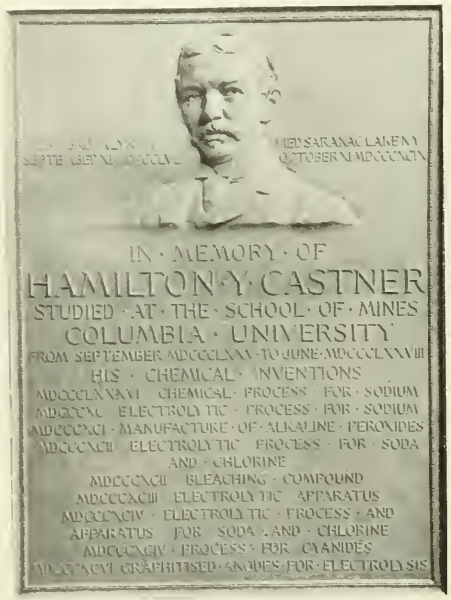
We call attention to these remarks of Dr. Kahlenberg on the development and the aim of physical chemistry, because we want to make some similar remarks on electrochemistry. Electrochemistry is often spoken of as the youngest branch of electrical engineering. This is correct as far as the industrial success is concerned. On the other hand, it should not be forgotten that electrochemistry is as old as electrical engineering. When Volta deviced in 1800 a cell by which chemical energy was changed into electrical energy, he was an electrochemist; and in 1807 Davy isolated the elements potassium and sodium by electrolysis of fused caustic soda and caustic potash and thus succeeded in bringing about new chemical reactions by means of the electric current. True, there was afterwards a long period in which industrial electrochemistry made practically no headway; but during this period, beginning with Faraday, the foundations were laid of modern theoretical electrochemistry.

It is out of place to sketch here the splendid development in recent years of industrial electrochemistry. The progress has been rapid and the success sweeping and the outlook for the future is very bright, especially as it becomes more evident every day that electrochemistry is only in the beginning of its industrial development, especially in this country with its enormous resources. The progress in future promises to continue to be rapid, but in order to be healthy, progress must be made on conservative lines. Industrial electrochemistry must remain in touch with theoretical electrochemistry and physical chemistry in general. It is a very good symptom—which was manifest to every one who attended the first two meetings of the American Electrochemical Society—that there is in this country good will and good feeling between electrochemical engineers and scientists, that both classes of electrochemical workers feel that they must stay together.

Electrochemistry is only a special branch of physical chemistry. Electrochemical scientists must be allowed to push forward on any road that seems to promise success. The roots of electrochemical science are in general physics and chemistry, and no progress in these sciences is so remote from the subject of electrochemistry that it should not be carefully watched by electrochemists. There is no pure science which cannot be eventually applied to the welfare of mankind. The practical man should not despise theories which at first seem to be "of scientific interest" only; and the theorist should never forget that as Dr. Kahlenberg puts it, science is for man, not man for science.

## THE CASTNER MEMORIAL TABLET.

A distinguished audience attended the ceremonies of the unveiling of the beautiful bronze tablet in Havemeyer Hall, School of Mines, Columbia University, at 4 o'clock, on Tuesday afternoon, December 10, 1902. Addresses were delivered in the large chemical lecture room by Dr. Chas. F. Chandler, dean of the School of Mines and the professor under whom Mr Castner studied chemistry for three years; by Dr. Marcus Benjamin, of the United States National Museum at Washington, who, as a classmate of Mr. Castner, related some personal reminiscences illustrating his characteristics as a student and investigator, and by Prof. Joseph W. Richards, of Lehigh


IN · MEMORY · OF
HAMILTON·Y·CASTNER
STUDIED · AT · THE · SCHOOL · OF · MINES
COLUMBIA · UNIVERSITY
FROM SEPTEMBER MDCCCLXXV · TO JUNE · MDCCCLXXVIII
HIS · CHEMICAL · INVENTIONS
MDCCCLXXVI CHEMICAL · PROCESS · FOR · SODIUM
MDCCCXC ELECTROLYTIC · PROCESS · FOR · SODIUM
MDCCCXCI · MANUFACTURE · OF · ALKALINE · PEROXIDES
MDCCCXCII ELECTROLYTIC PROCESS · FOR · SODA
AND · CHLORINE
MDCCCXCII BLEACHING · COMPOUND
MDCCCXCIII ELECTROLYTIC APPARATUS
MDCCCXCIV · ELECTROLYTIC · PROCESS · AND
APPARATUS FOR SODA · AND · CHLORINE
MDCCCXCIV · PROCESS · FOR · CYANIDES
MDCCCXCVI GRAPHITISED · ANODES · FOR · ELECTROLYSIS

University, representing the American Electrochemical Society. Dr. Chandler related the history of the inception and development of Mr. Castner's inventions, while Dr. Richards discussed more particularly the relation of Castner's work to the aluminum industry, the general question of his pioneer work in electrochemistry and the effect of his inventions on industrial and economic progress. The audience then filed into the corridor, where, in the presence of Mrs. Castner and the company which had gathered to do her husband honor, Dr. Chandler, after a few impressive and appropriate words of dedication, drew aside the curtain.

## ELECTROLYTIC PROCESSES.

In his presidential address delivered before the (British) Institution of Electrical Engineers, Mr. James Swinburne makes some very interesting remarks on electrolytic processes.

"This [electrolysis] is a branch of industry in which it is very difficult to tell our limits. In electrolytic copper-refining our limit is that of the copper wanted. Our electrolytic industries suffer mostly from the limits of intelligence of the investing public. It is assumed that we cannot do electrolysis in England because we have no water-power. This is only an excuse for inactivity. As already* explained, we can do just as well without water-power. A blast furnace is much more valuable than a waterfall of similar power, because it is near coal and in an industrial district. Moreover, as already explained, the cost of electrical energy is a small portion of that of most electrolytic products. At first electrolysis was to be applied to copper refining, then to caustic soda.

"The output of electrolytic caustic is really rather limited by the demand for bleach. What is urgently wanted is some other way of storing and carrying chlorine. Steel bottles and compression plant are an unsatisfactory solution. What are the limits in the way of electrolyzing fused salt? They are all incidental limits. The containing vessel is a difficulty. Sodium vapor attacks all silicates. Sodium distills near the temperature of fused salt. If not volatilized it forms a conducting bridge from the cathode. It attacks iron, though slowly. Hot porcelain and earthenware conduct electrolytically—as, by the way, the maker of electric frying pans knows—hot chlorine attacks metals, even when dry, and hot carbon cannot be exposed to the air. In addition, sodium, and perhaps chlorine, are soluble on hot salt, and traces of sulphate in the salt act as carriers, as sulphate and sulphide. I could a tale unfold if I read out laboratory notes of sodium experiments on a large scale. The difficulties are all incidental though, and I have little doubt electrolytic sodium at a low price will be in the market soon, and will affect profoundly many chemical and metallurgical industries. I would like an opportunity to continue experiments myself, but others will, I feel certain, soon succeed.

"In metallurgy electrolytic solution processes are in use or on trial for the more valuable metals, such as copper and nickel. The reaction between chlorine and metallic sulphides at high temperatures brings the whole domain of sulphide ores under our sway. Thus a sulphide, say galena, is treated with chlorine, which gives off the sulphur, as sulphur which is condensed and sold, making chloride of lead. The silver is extracted by stirring with a little lead, and the fused salt is then electrolyzed, yielding pure desilverized lead and chlorine. The process is thus self-contained, yielding sulphur, lead and silver. It is specially applicable to mixed refactory ores which are now nearly valueless and very plentiful, and contain much metal content, such as the mixed lead-zinc sulphides of America or Australia. These reactions have been proved on the large or ton scale, and there is no technical difficulty. Unfortunately mine people are somewhat ignorant of electrical matters, and it is exceedingly difficult to get them to understand or appreciate a process like this, capable though it may be of paying good dividends on very large capitals indeed.

"In all these metallurgical extractions we may roughly take the cost of energy as a farthing per kilowatt hour for steam, and half that for gas. Allowing a rough average pressure per cell, we may take it that electric energy costs $500 per ton, or ton equivalent by steam, and $250 by gas. That would be $15 a ton for zinc, $5 for lead, $15 for copper and iron by steam, and half these figures by gas-power. This means that the metallurgy of all sulphides, except, perhaps, iron, is within our grasp. It may pay to make a pure iron, free from phosphorus, silicon, manganese and carbon at something under $50 a ton from pyrites ores (which may also contain zinc, nickel, copper, etc.), and then, add exactly the desired amount of other constituents or 'physic' to produce with accuracy steels of special grades.

"But our limit in electrolysis in this country [England] is almost entirely human inertia. Commercial and financial people do not understand it, and fight shy of it. But our technical people are nearly as bad. The pure physicist, as a rule, takes no interest in electrolysis or physical chemistry, and thinks it belongs to the chemical class room on the other side of the passage. The chemist thinks it is higher mathematics, and will have none of it; the mathematician thinks it may be an exercise in differential equations; but they are all agreed that it is a sort of continental fungus which flourishes with no roots, and that it is beneath the attention of a scientific man to know enough about it to give a reason for the broad statement that it is all nonsense."

* See *Electrochemical Industry*, Dec., 1902, vol I page 118.

## ELECTROLYTIC REFINING OF GOLD.

By D. K. TUTTLE, PH.D.
Melter and Refiner, U. S. Mint, Philadelphia.

The problem of refining silver containing small amounts of gold, and other impurities, by electrolysis has been solved, and the industrial establishments of to-day treat practically the entire silver product of our mines in this manner.

Only the gold residues reach the mints. Indeed, the scarcity of silver deposits at the Government institutions has been a serious inconvenience, since the usual acid refining methods require a large amount of that metal as parting material in treating the gold bullion received.

The great mass of gold deposits contain some silver and are usually too impure for either coinage or industrial use without refining. Some contain platinum, which is lost in the usual wet processes.

It has been the practice to alloy the gold in the deposits with 2½ times its weight of silver, and subject this mixture to the action of nitric or sulphuric acid. In consequence of the very limited deposits of silver, it is necessary to use the same silver repeatedly as parting material, at a great expense for acid. If 2½ times as much impure silver as of gold came to the mints, the parting processes would not be so wasteful.

The only process for directly refining gold electrolytically that is known to have been reduced to practice is that patented by Dr. Emil Wohlwill, Hamburg, Germany, United States patents 625,863 and 625,864.

The feature protected by patent is the electrolyte. This is composed of gold chloride solution rather strongly impregnated with free hydrochloric acid, and it is in this latter point that the significance of the invention lies. If a gold anode is placed in a neutral or only slightly acid solution of gold chloride, opposed by a suitable cathode, gold will be deposited by an electric current, but little or no gold will be dissolved from the anode. Free chlorine is given off, a result not to have been anticipated since chlorine is an active solvent for gold. Upon the addition of free hydrochloric acid to the bath, a point is reached where the chlorine at the anode is suppressed, and gold passes into solution, equivalent for equivalent, to that deposited. The strength of the electrolyte is easily maintained by such additions of gold chloride from time to time as will be equivalent to the copper, platinum, etc., dissolved from the anode, and not deposited on the cathode. The operation is continuous until the solution becomes highly charged with impurities.

The Wohlwill process is in use in the two great refineries of Germany—the Norddeutsche at Hamburg and that at Frankfurt (formerly Dr. Rössler). In a private letter to the writer, Dr. Wohlwill states that gold has been refined by electrolysis in the Hamburg plant since 1878, uninterruptedly, and that now practically all the gold refining done in Germany is effected by this method.

Correspondence with the patentee resulted in the purchase of a right to use the Wohlwill patent in the mint at Philadelphia, and a plant has been introduced which is being gradually enlarged.

### PROCESS.

The apparatus consists of first: A dynamo, which, when run at its normal capacity, requires 5 horse-power and furnishes a current of 600 amperes at 6 volts. The machine having been designed with a view to experimental work, a rheostat in the field-winding enables us to regulate the current between 100 and 600 amperes.

ELECTROLYTIC REFINING ROOM, U. S. MINT, PHILADELPHIA.

Second: The cells, which are of white porcelain (Berlin ware), are 15 inches long x 11 inches wide and 8 inches deep. These are filled with a prepared solution of gold tri-chloride containing 30 grammes of gold per litre (3 8-10 Troy ounces per gallon), the depth of the solution being such as not to entirely submerge the anodes. In each of these cells are suspended 12 anodes and 13 cathodes, *in multiple*. The anodes are each 6 inches in length, 3 inches wide and ¾ inch thick. The corresponding cathodes are of fine gold and rolled down to 1/100 of an inch in thickness. The distance between anode and cathode is 1½ inches. In our present working seven cells are placed end to end on a bed of sand underlying which is a series of steam pipes by which the temperature of the bath may be raised and maintained at any desired degree. At present our cells are kept at from 50° to 55° C. The increased temperature serves to reduce the voltage required, and at the same time to diminish the amount of free acid necessary to suppress evolution of chlorine at the anodes.

Circulation of the electrolyte by mechanical means is necessary to secure uniform disintegration of the anode and deposition of the gold.

The seven cells in use are connected up, *in series*, with the dynamo, which is at present regulated to furnish 100 ampères. The tension between the terminals of the seven cells varies from 4½ to 5 volts, dependent upon temperature, strength of solution, etc.

The chemical equivalent of gold is very high, and the electromotive force required for the deposition of gold is very low, so that the power necessary for running the plant is insignificant. With only seven cells of our plant in operation, we are refining about 5,000 ounces per week, with the expenditure of about 1 horse-power. One attendant suffices to manage the work, with the occasional assistance of a second workman.

The cost for hydrochloric acid in the bath is 20 cents per 1,000 ounces of deposited gold.

We can increase our refining capacity to 50,000 ounces per week with our present plant.

Beside the advantage the process offers for the refining of gold with an insignificant consumption of acid, with little labor, and small expenditure of power, an important one should be mentioned, viz., the recovery of any platinum present in the bullion. This dissolves, but is not deposited with the gold. When the electrolyte becomes sufficiently charged with platinum, the gold is first precipitated by sulphur dioxide, and removed. Then the platinum remaining in solution is separated as ammonium platinum chloride. Lastly, the copper is recovered by passing the wash waters over iron scrap.

With these advantages to its credit, the process has limitations which are serious ones. Any silver in the anodes will, of course, be converted into insoluble chloride, and if the percentage be small will fall to the bottom of the containing tank as "slimes." But if the amount of silver exceed 5 per cent. the chloride tends to adhere to the anode, as a crust, which must be mechanically removed.

Furthermore, any considerable quantity of copper present in the bullion to be treated is undesirable, since the electrolyte, in that case, must be renewed inconveniently often.

There seems to be reason to think that any electrolytic process for parting and refining gold will not have the same success in this country in our industrial plants as it met in Europe. The Australian, South African and Hong Kong native gold is very much purer than even our California nuggets, and they were very much better than our recent finds in Alaska.

Hong Kong gold is reported as containing .975 gold, .020 silver, .0005 platinum, .0005 iridium.

Some recent consignments of Klondike gold to this mint varied from .776 gold to .834 gold, .219 silver to .101 silver, with no showing of platinum or iridium in the electrolyte.

Such bullion can only be successfully treated by the "Wohlwill" process when blended with a higher-grade gold. We prefer not to treat bullion having a fineness of less than .940 gold.

Again, the Government conditions for the gold producer here are much more favorable than in other countries. At any United States mint or assay office the depositor is entitled to receive promptly upon assay of his bullion all the gold it contains in the form of gold coin or draft on the treasury, less some slight charges. If the amount of the deposit be large he may even receive an advance of 80 per cent. on its approximate value at the time of making the deposit. Under these circumstances the question of *interest* becomes an important item with the industrial establishments. With a given output per diem, several times the value will be locked up in solution, anodes, cathodes and material in various stages of leaching, melting, etc.

It is to be feared that with the liberal system in vogue in this country, the depositor will still find it to his advantage to deliver to the Government high-grade, but not very pure, bullion for spot cash, pay the slight charges and leave the melter and refiner to wrestle with the refining.

For the patrons of the United States mint, however, the "Wohlwill" process has been a great boon. The gold bars furnished have been exceptionaly high (999.8), and this grade is especially sought by makers of dental gold and leaf. Under slight pressure it coheres and compacts into a reguline mass, as perfect as if melted and poured in a mould. A medallion head of Washington was made from spongy electrolytic gold by simple pressure in the die press, and the result was a perfect success, too soft for wear, but a beautiful medal.

This especially high-grade gold is being distributed to appreciative customers at many points distant from Philadelphia.

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## THE PRESENT METALLURGY OF ALUMINIUM.

By Joseph W. Richards, Ph.D.

*President of the American Electrochemical Society.*

THE aluminium now being manufactured is being made by one process only, viz., the electrolysis of alumina dissolved in a bath of melted aluminium-sodium double fluoride. The principle involved in this process was discovered by Paul L. V. Héroult, in France, and Charles M. Hall, in the United States, in 1886. The principle is easily understood when once known; it is, that the melted double fluorides of aluminium and more electropositive metals can dissolve a considerable proportion of their weight of the relatively infusible alumina, and that when such a solution is electrolyzed, aluminium and oxygen appear at the two electrodes until the dissolved alumina has been almost entirely eliminated; and that, by the addition of fresh alumina the process can be made continuous, while the solvent bath material remains unaffected by the operation.

Before describing the efforts of Hall and Héroult, it may be well to say that the process is the invention of these two investigators alone, and the hysterical attempts of Mr. A. Minet to claim a share in the discovery and application of this principle, especially his temerity in calling the present process the Minet Hall process, are without the slightest basis or justification in actual fact. In a recent German monograph, Mr. Minet devotes 19 *lines* to the original patent of Mr. Héroult (by which some 3,000 tons of aluminium is manufactured yearly), 32 *lines* to the patents of Hall (by which some 6,000 tons is made yearly), and *20 pages* to the description of Minet's process, by which not a pound is being commercially manufactured, nor is it at all likely to be. Hall's and Héroult's processes were discovered, and patents applied for, in 1886; Minet himself dates his first experiments from February, 1887. Minet makes a bath of 60 parts sodium chloride and 40 parts aluminium-sodium chloride or fluoride, and electrolyses this bath, producing therefrom aluminium and chlorine, or perhaps, fluorine, and regenerates the bath by piling alumina around the anode where, by the simultaneous contact with the carbon anode and the gaseous halogen, it is partly decomposed and enters the bath as aluminium fluoride. Such, at least, is what Mr. Minet says happened to his bath; but, however that may be, no sodium chloride is used at all in the present process of manufacture, and while Minet may make a Quixotic claim that the present is the Minet-Hall process, no court would sustain his claim, particularly since he only began his experiments the year *after* Hall and Héroult had applied for their patents.

Turning now to the Héroult process, it was first conceived by him in 1886. At the Metallurgical Congress at Paris, in 1900, Héroult described how he stumbled across it. He was attempting to electrolyze melted cryolite, the native double fluoride of aluminium and sodium, $AlF_3.3NaF$, with an iron cathode and carbon anode, and adding some double chloride of aluminium and sodium, $AlCl_3.2NaCl$, to the melt to make it more easily fusible. He obtained aluminium alloyed with his iron cathode, but no evolution of either chlorine or fluorine at the anode, yet the anode was attacked and evolved a gas. He concluded that some oxide had gotten into the bath, whose

oxygen was attacking his anode. He took up this clue, and on testing the aluminium-sodium double chloride which he had used, found that it had been largely converted into alumina by the moisture of the air, and thus alumina had gotten accidentally into the bath. On adding pure alumina, later, he found that this explained the question, and that the electrolysis produced only aluminium and carbonic oxide.

Héroult was then a student, twenty-three years old, and after taking out his patent in France in April 23, 1886, number 175,711, he went for advice to the established manufacturer of aluminium by the sodium process—Pechiney at Salindres. Here he was advised that the uses of pure aluminium were so limited that his process was of little value, and that if he would put his attention on producing cheaply the alloys of aluminium and copper or iron he would start a much greater industry. He accordingly set to work on his idea of electrolyzing pure alumina melted alone in the electric furnace, using a copper or iron cathode, and in 1887 took out additional patents for this alloy process. Going thence to Switzerland, he worked for a year at the Rhine Falls, producing only aluminum alloys, such as the bronze, by this alloy process. Finding in 1888 that Hall, in America, was producing commercially pure aluminium by a process analogous in principle to his original patent, Héroult resurrected his earlier pure-metal process and, with the aid of Dr. Kiliani, set to work making pure aluminium, which he placed upon the market only some twelve months after Hall in America had commenced operations on a commercial scale.

The process of Heroult, patented in 1886, describes putting alumina into a carbon crucible, and adding cryolite in sufficient quantity to render it fluid at a moderate heat. The crucible itself serves as cathode while a carbon anode dips into the bath. The crucible is placed inside a larger graphite crucible, and the space between the two filled with graphite, into which dips the negative carbon. A cover having holes for the insertion of the conducting carbons is provided, and a layer of clay or loam put on top to exclude air and gases. Héroult stated that a current of three volts was sufficient to produce decomposition, but that a convenient strength of current for a crucible 20 centimeters deep by 14 centimeters inside diameter, with a carbon anode 5 centimeters in diameter, was 400 amperes, which required a potential of 20 to 25 volts. The crucibles were placed in a wind furnace and kept hot by a fire, during the electrolysis. The idea of a continuous operation by adding fresh alumina is conspicuous for its absence in this description, as all the arrangements point to the idea of running a charge in the crucible, tightly closed, then lifting it out of the furnace, removing the luting and covers, and removing the contents of the crucible.

The probabilities are that Héroult did not make more than a few ounces of metal in this way until 1889, when, hearing of the success of Hall in America, he started, with Dr. Kiliani's assistance, to develop his process into commercial shape, and it was not until September, 1890, that his company was selling pure aluminium.

How the process has been developed abroad we know only by the results. Dr. Kiliani patented a revolving furnace, with a movable anode, but this has been abandoned. The European Works, operating under Héroult's patent, are not open to the public, and no details of their working are given by the managers. It is the writer's opinion that the method of working adopted in these works is practically that used by Hall in America since 1888, and that the great secrecy of the European makers is used principally to avoid it being known how closely they have copied the American style of apparatus. This opinion may be wrong, but it explains the situation so well that it commends itself as the true reason of their secrecy.

The plants working with licenses under the Héroult patents are the Aluminium-Industrie-Aktien-Gesellschaft, at Neuhausen, Switzerland, 4,500 horse-power; at Rheinfelden, Baden, 5,000 horse-power, and at Lend-Gastein, near Salzburg, Austria, 3,000 horse power, also the Societe Electrometallurgique Française at La Praz, Savoy, 3,000 horse-power, and the British Aluminium Co., at Foyers, Scotland, 6,000 horse-power. Part of the power of all of these plants is used for making calcium carbide, and the proportion used for aluminium is not exactly known; it is probably not over 12,000 horse power in all of those plants put together, and possibly less.

Mr. C. M. Hall approached the subject from the standpoint of trying to find a fluid melted salt in which alumina would dissolve and out of which it could be electrolyzed. As he has several times explained to the writer, he had in mind the analogy to dissolving a salt, such as copper sulphate, in water, and obtaining the ingredients of the salt at the two electrodes without decomposition of the water. For this end, he experimented to find a melted salt which would (1) dissolve alumina freely, (2) conduct electricity, (3) yield only aluminium and oxygen on being electrolyzed, (4) not volatilize or deteriorate on continued use. After a long and arduous investigation, in which almost all the single and double salts of aluminium were tested, and many fusible salts of other metals, Mr. Hall discovered that the double fluorides of aluminium and the more electropositive metals were the only salts which possessed the above qualifications. The process was first operated in February, 1886, and patents applied for July 9th of the same year.

During this period, in May, 1886, Mr. Héroult, of France, had applied for a United States patent corresponding to his pure metal process, already described. The patent office instituted interference proceedings, with the result that it was found that Mr. Hall had made his invention and practised it before any publication of Mr. Héroult's process had been made, and was therefore, entitled to the United States patent. In consequence of this decision the patent in this country was issued only to Mr. Hall. Later, Heroult obtained United States patents for his alloy process, and the same was installed experimentally at Boonton, N. J., but it was not a commercial success.

Mr. Hall applied on July 9, 1886, for a single patent, which was issued on April 2, 1889, after division of the original application and re-application. The patents are numbered 400,664, 400,665, 400,666, 400,667 and 400,766. They cover variations of the original principle. For instance, Mr. Hall found that the double fluoride of aluminium and potassium or lithium was a very easily fusible salt, and possessed the required qualifications for use in his process, being of particularly low specific gravity. The cost of these salts is the particular item in which they are inferior to the corresponding sodium salt. Again, the double fluorides of aluminium and the alkaline earth metals are also effective, with the drawback of a high specific gravity, greater than that of aluminium, and therefore more suitable for producing alloys of aluminium than the pure metal.

Two of the broadest claims of Mr. Hall are as follows, from patent number 400,766:

"1. As an improvement in the art of manufacturing aluminium, the herein described process, which consists in dissolving alumina in a fused bath composed of the fluorides of aluminium and of a metal more electropositive than aluminium, and then passing an electric current through the fused mass, substantially as set forth.

"2. As an improvement in the art of manufacturing aluminium, the herein described process, which consists in dissolving alumina in a fused bath composed of the fluorides of aluminium and sodium, and then passing an electric current, by means of a carbonaceous anode, through the fused mass, substantially as set forth."

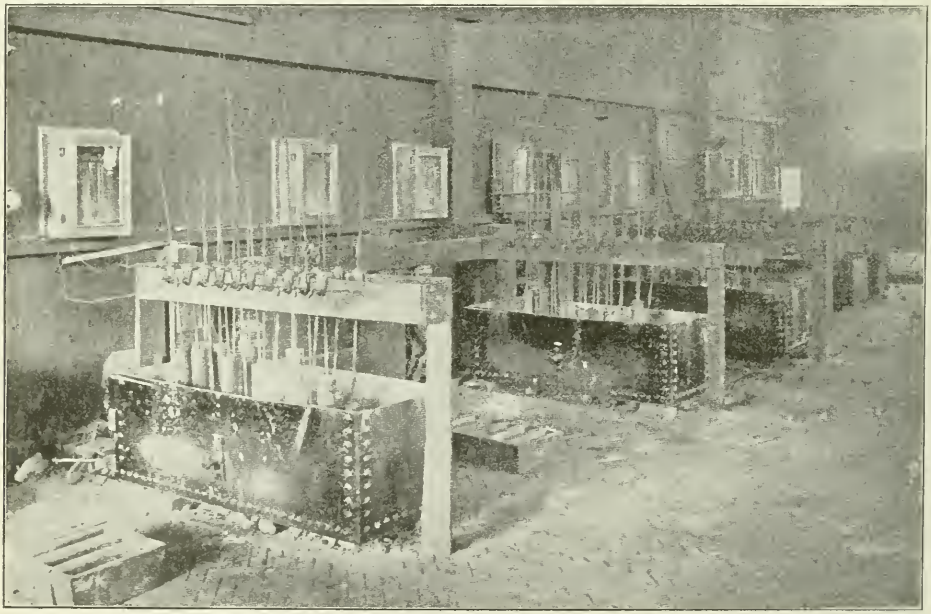
The other patents enumerated claim specifically the use of double fluoride of aluminium and potassium to form the bath, also of lithium fluoride in the bath in place of part of the sodium or potassium fluoride, also the use of calcium fluoride in the bath, and of the double fluorides of aluminium and

alkaline-earth metals. In patent 400,667 especial emphasis is laid on preserving the continuity of the operation by adding alumina as the bath becomes impoverished in alumina, and removing aluminium from the bath, by tapping or ladling out, without interrupting the process.

The Hall process first began commercial operations at Pittsburg, using 125 horse-power, in November, 1888, and producing 50 pounds per day. Since then, the history of the process is one of steady increase in size and efficiency. In place of small cast-iron pots, taking 1,800 ampères and requiring 8 volts to run them, and requiring over 2 horse-power to each pound of aluminium produced daily, there are now used large wrought-iron pots, taking 10,000 ampères and requiring but 5 to 6 volts each, and producing probably 1½ pounds of aluminium daily for each horse-power applied. In place of the 125 horse-power at Pittsburg, there is now in use 10,500 horse-power at Niagara Falls and 5,000 horse-power at Shawinegan Falls, Quebec.

The principle of the process, however, retains its original

All the impurities of the alumina used pass into the metal produced, and to obtain pure metal it is therefore absolutely necessary to use the purest alumina. This requirement has led to considerable improvement in the manufacture of alumina, the Baeyer process being in considerable use both here and abroad, while in addition to this, Mr. Hall has invented a lime-process of wet chemical treatment, which is installed on a large scale at East St. Louis and is producing alumina of the highest quality; he has also patented the method of purifying bauxite or crude alumina by mixing it with sufficient reducing agent to reduce the impurities present, and then melting down the mixture in an electric furnace. The result of the last process is a dense, granular purified alumina, in form and composition very suitable for reduction. The lime process is the subject of Hall's United States patent 653,167 of December 4, 1900; while the electric-furnace method of purification is in United States patents 677,208 and 677,209 of June 25, 1901, and 706,553 of August 12, 1902. The Pittsburg Reduction Co., operating the Hall process, also bakes its own carbon elec-



A HALL ALUMINIUM BATH.

simplicity. The bath material consists of the double fluoride of aluminium and sodium; alumina is dissolved in this up to a maximum of 15 to 20 per cent. As the alumina is removed by electrolysis and the resistance of the bath goes up, fresh alumina is stirred in. The 3-inch carbons used carry each 250 ampères of current, and are kept at approximately an inch from the negative electrode, which is the melted metal in the bottom of the pot. The large size of the pot and correspondingly heavy ampèrage passing through develops enough heat in the electrolyte to keep the contents melted without the assistance of exterior heating, which is thus rendered unnecessary by the scale of the operation. The metal formed sinks in the bath because its specific gravity, melted, is 2.54, while that of the bath varies between 2 and 2.35, at most. The temperature of the operation is 900° C. (1,650° F.). One bath will continue in uninterrupted operation several months, the carbon anodes being renewed as they burn away, which they do at the rate of 1 pound of anode per pound of metal produced.

trodes by an electric-furnace process described in Hall's United States patent 705,076 of July 22, 1902.

The commercial production of aluminium in America is, therefore, wholly by the application of Hall's process of electrolytic reduction, supplemented by Hall's lime or electric-furnace process of purifying alumina and the same inventor's process of baking carbon electrodes. It was not the purpose of this article, however, to enter into detail on the commercial side of the production of aluminium, and we will conclude by discussing the reactions taking place in the process, *i. e.*, by regarding the scientific aspect of the process.

First, as to the facts. Cryolite, the sodium-aluminium double-fluoride, melts at 800° C. When melted, it is transparent and one can see through several inches of it to the bottom of the vessel containing it. If powdered alumina is stirred into it, it largely dissolves at once, without ebullition or evolution of heat or any signs of chemical action. If a large amount is added at once, some will be seen at the bottom

of the melt gradually dissolving and disappearing. About 20 per cent. of the weight of the bath can be thus taken up, and the bath remains homogeneous; if over 25 per cent. is added some remains undissolved at the bottom. Neither the bath material alone or the solution containing alumina wets, *i. e.*, adheres to, carbon. Carbon rods or even powdered carbon stirred into the bath, rise to the surface and emerge without the bath material sticking to them. On passing a direct electrolytic current through this bath aluminium appears at the cathode, and oxygen at the anode. If the anode is of carbon, carbonic oxide is there evolved; if it is of bright copper, a skin of cuprous oxide first forms on it, and afterwards oxygen is evolved. If the alumina in the bath is allowed to become exhausted, fluorine commences to evolve at the anode; if a very high current density is used sodium vapor shows itself at the cathode. The working temperature of the bath is 900 to 950 C., and its specific resistance is about 3 ohms per centimeter cube.

Mr. Adolphe Minet has made a number of measurements of the resistance and electromotive force required for decomposition in baths containing 60 per cent. of sodium chloride, and it is, therefore, not at all certain that his conclusions apply to the present manner of manufacturing aluminium. He concludes that in a bath containing sodium fluoride, sodium chloride and aluminium fluoride, mixed together, the aluminium fluoride must be decomposed, because it is the weakest of the three salts, and the salt thus removed may be returned to the bath by piling alumina around the anode where it may be converted into fluoride by the evolved fluorine. He claims that when alumina is added to such a bath it does not dissolve, but remains mechanically suspended, and so regenerates aluminium fluoride by being decomposed by the fluorine evolved at the anode. As stated above, the presence of an excess of sodium chloride vitiate all Minet's conclusions, as applicable to Héroult's and Hall's processes, and, furthermore, all the phenomena of the electrolysis of Hall's and Héroult's baths point to a different explanation.

Héroult himself advanced the even less plausible theory that sodium was primarily evolved at the cathode and fluorine at the anode, that the sodium then acted upon the aluminium in the electrolyte as aluminium fluoride and reduced out its metal, while the fluorine at the anode acted upon the alumina suspended (not dissolved) in the melt, and set free its oxygen, forming aluminium fluoride. This theory is such a maze of contradictions as to be indefensible. Primarily, the disappearance of alumina stirred into the bath is proof of its becoming incorporated into the electrolyte, and any electric current passing through would separate aluminium at the cathode in preference to the more positive sodium. The theory of Héroult, unsustained by any experimental proofs to establish his position, is certainly untenable.

In the writer's opinion, and from his repeated observation of the process and experimenting with it in various ways, the conclusion of Mr. Hall that he really has a solution of alumina in a fluid bath analogous to a salt dissolved in water, is the best explanation of the facts. The alumina dissolves apparently like sugar disappearing in water, without ebullition, evolution of gas or heat, or any appearance of chemical action. If the result is an oxyfluoride bath, as some think, it may be well to note that an oxyfluoride is merely a combination of $Al^2O^3$ and $AlF^6$, and the union, if it exists at all, is chemically a very weak one. When a salt goes into solution in water, the hydrate theory of solution assumes the existence of possible combinations of salt and water in the solution, but of such a weak character of combination as to practically be negligible as compounds. With these facts in mind, it appears that the statement of Mr. Hall that his alumina *goes into solution* in the bath is a very exact statement of the phenomenon.

As concerns the decomposition of the bath, everyone who has worked with the process knows that aluminium appears at the cathode and oxygen at the anode. The most evident inference is that the alumina in solution is decomposed, and its constituents appear at the electrodes. Anyone who would maintain that the primary electrolysis proceeds otherwise and that one or both of these products are secondarily produced, must certainly shoulder the burden of proof to support his view. But, when we come to analyze the reaction, and discuss the probability of secondary reactions occurring, we find the probabilities all in favor of the decomposition into aluminium and oxygen being primary.

There are present in the bath, or, at least, go into its composition, sodium fluoride, aluminium fluoride and alumina. The heats of formation and voltages theoretically necessary for decomposition of these salts are as follows:

Sodium fluoride (Na, F) = 109,700 calories, requiring 4.7 volts.

Aluminium fluoride (Al, $F^6$) = 296,000 calories, requiring 4.0 volts.

Aluminium oxide ($Al^2$, O) = 392,600 calories, requiring 2.8 volts.

With these substances going into the composition of the bath there is not the slightest doubt but that aluminium and oxygen should be primarily separated out at the electrodes on passing the current. The facts are that these products do appear, and the burden of proof is certainly on anyone who would maintain that the reaction is in any way different from the above. If a carbon anode is used, carbonic oxide appears, and only traces of carbon fluoride; if copper is used, it coats itself with oxide, not with fluoride, and afterwards pure oxygen is evolved. The writer cannot understand how anyone can doubt the primary evolution of oxygen and aluminium from the bath, if they are acquainted with the details of the process and its mode of working.

Haber and Geipert published in the *Zeitschrift für Elektrochemie* for 2d and 7th January, 1902, the results of some laboratory tests of this process on a rather large scale, using a current up to 400 amperes. They obtained about 50 per cent. of the theoretical output, and remark that the electrolysis of this solution of alumina proceeds as quietly and regularly as an analytical determination in aqueous solution. They determined to their complete satisfaction that only traces of carbon fluorides were evolved during the electrolysis, and that the bath will not take up uniformly above 20 per cent. of its weight of alumina. With their small apparatus they found a current density of .3 amperes per square centimeter of floor surface kept the bath fluid, while in large manufacture one-third that much suffices. The difference is due entirely to working with 300 amperes or several thousand. They used a working voltage of 8.5, whereas on a large scale only two-thirds that voltage is necessary, using the lower current density.

Prof J. W. Langley has recently given, in the "Transaction of the American Electrochemical Society," Vol. II, page 200, the results of measurements of the counter-electromotive force in electrolyzing alumina dissolved in melted cryolite at 1,010° C., using 1,000 amperes of current. The measurements were only approximate, but showed a counter-force rising to 1.22 volts during continuous electrolysis by 5 to 10 volts applied. This is not the disruptive work of the current, but, as Prof. Langley happily phrases it, is "the instantaneous value of the counter electromotive force existing *during the passage of the current*." It is very probably the measure of the tendency of metallic aluminium to decompose the carbonic oxide gas at the anode and form the lowest oxide of aluminium. But, the current is decomposing the highest oxide of aluminium, and, therefore, the voltage absorbed in decomposition is higher than the counter-electromotive force.

The writer has satisfied himself, from measurements of the current in amperes passing through the bath, using different potentials, that the chemical work being done by the current is represented by nearly 2.2 volts, which corresponds to the decomposition of alumina (2.8 volts) minus the energy furnished by the oxidation of the carbon (0.6 volts). Prof. Lang

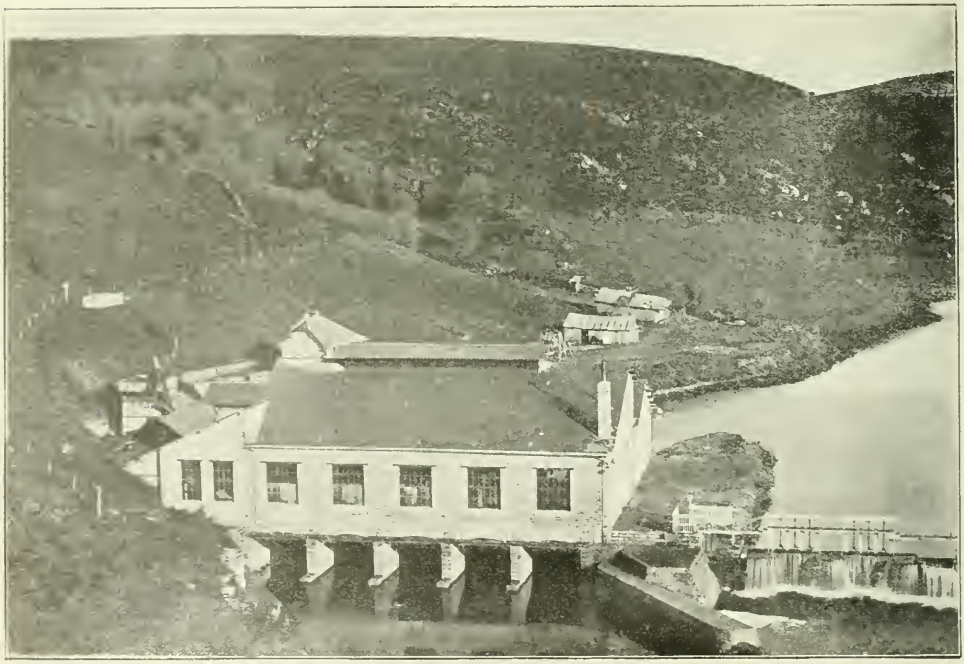
determination of the counter-electromotive force being 1.42 volts is not inconsistent with this; it simply means that if the current is suddenly thrown off, the ions at the electrodes do not tend again to form alumina and carbon, but sub-oxide and carbon, with a total energy evolution measured by 1.22 volts.

It is a pity that a process of such beautiful simplicity, theoretical interest and commercial importance has not been more closely studied, and more definitely described. Commercial reasons have doubtless actuated the workers of the process in keeping all its details as secret as possible, but it is to be hoped that the awakening of electrochemical industries which has taken place in the last year or two will soon touch this field, and help us to fill some of the gaps in the scientific understanding of this process. The writer is convinced that a clearer understanding of the modus operandi of this process would undoubtedly lead to fruitful results in the application of similar principles to the extraction of some of the other electropositive metals.

white snow mountains with their waterfalls, available for generating power.

Among the papers read at the congress was one of special interest, as it dealt with an entirely new electrochemical industry. Its author was Mr. Charles Bertolus, electrometallurgist at Saint-Etienne (Loire); and the subject of the paper was the manufacture of different kinds of steel in the electric furnace in the Kerrousse plant of Keller, Leleux & Co. For a copy of the paper, as well as for the cuts and for some valuable additional notes, we are indebted to Mr. P. McN. Bennie, European manager of the International Acheson Graphite Co.

The plant at Kerrousse, near Hennebont (Morbihan), was erected by Keller, Leleux & Co. for the purpose of manufacturing calcium carbide; but when it was nearly completed, the French courts handed down a decision awarding to Mr. Bullier all patent rights to make calcium carbide in France, so that the plant at Kerrousse was prevented from starting the manufacture of carbide. As the apparatus for electrometal-



KERROUSSE PLANT.

## A FRENCH PLANT FOR MAKING STEEL IN THE ELECTRIC FURNACE.

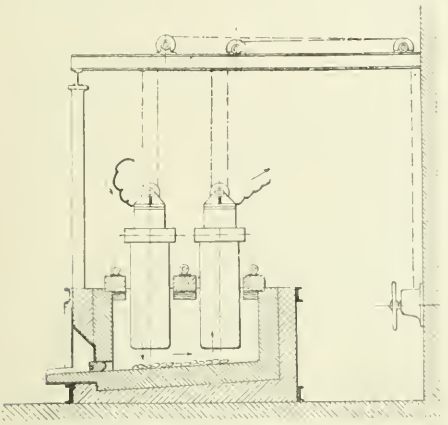
In Europe, France may be considered to be the country par excellence of water-power development. Especially in the French Alps a great number of hydro-electric stations were erected in recent years, and a remarkable rise of electrochemical industries took place in connection with this development. As the possession and development of a water-power in France is governed by certain laws, this industrial development was somewhat influenced by legal restrictions. To thoroughly discuss the legal and the industrial aspect of the case, all those interested in water-power development in France, united last fall at Grenoble in the "Congrès de la Houille Blanche," *i. e.*, in literal translation, "White Coal Congress," attributing the poetical name "white coal" to the

lurgical operation had been installed, it was decided to utilize the plant partly for the manufacture of ferro-alloys and partly for making steel in the electric furnace. The latter process is described in the paper of Mr. Bertolus.

The plant at Kerrousse utilizes a waterfall of the river Blavet of about 550 horse-power. There are four vertical turbines each of 135 horse-power, coupled at will to a horizontal shaft driving two alternators of 200 kilowatts each, and two exciters. The alternators are designed to give current at three different voltages, according to the external circuit to which they are connected, and according to the special electrometallurgical process for which the current is used.

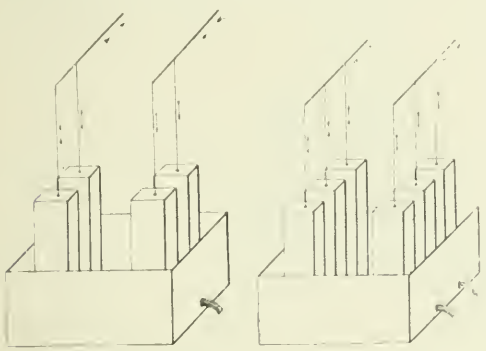
The furnace room is divided into two parts: one-half contains four electric furnaces for making ferro-alloys, the other half special electric furnaces for treating iron ores and making steel.

Mr. Keller, a member of the firm which owns the plant, obtained his first satisfactory results in the treatment of iron with his "two-electrode furnace. This furnace contains two vertical electrodes, placed side by side; the furnace has walls of brick and a refactory bottom. At each electrode a distinct



TWO-ELECTRODE FURNACE.

zone of high temperature is produced, and these two high temperature zones are in series with the fused or partly fused materials between them. Either high temperature zone may be separately regulated, by a simple movement of the electrodes. This two-electrode furnace has, however, two dis-



FOUR-ELECTRODE FURNACE. SIX-ELECTRODE FURNACE.

advantages: the capacity of the furnace is limited and the continuity of operation is interrupted whenever an electrode is to be renewed. These disadvantages are successfully overcome by using four or six or more electrodes, one-half of the electrodes being connected to the positive pole of the circuit, the other to the negative pole. It is evident that with this arrangement there is practically no limit of the dimensions of the furnace, and that a single electrode can be replaced without interrupting the whole operation.

In his first experiments Mr. Keller used the same apparatus for the reduction of the iron ore and for the subsequent conversion into steel. There was the disadvantage that both steps require different treatment. To enable economical reduction of the iron ores, the furnace must be able to accommodate a considerable quantity of the materials to be treated; on the other hand, for refining purposes a rather shallow furnace is required with the material held in a condition of perfect fluidity and easily accessible. These reasons lead to the adoption of two electric furnaces "en cascade" (in tandem), the upper furnace being intended for the reduction of the iron ores, and the lower furnace for the subsequent refining and purification process. As each furnace serves a special purpose, it is designed to meet the special demands of this purpose. This is the arrangement of the 375 horse-power furnace which we will describe later. It may be mentioned that Mr. Bertolus in his French paper always speaks of the "haut-fourneau électrique." Mr. P. McN. Bennie remarks that a new name seems necessary for this type in English; it might be translated as blast furnace, because the general appearance is that of the ordinary blast furnace, although in the electric furnace there is no "blast."

The upper furnace has four electrodes; the bottom is inclined towards the tapping hole. Above the fusion chamber of the furnace there is a column made of brick, and into this shaft the ores, the carbon for reduction, and the fluxes are fed. Below the tapping hole of the upper furnace, the lower furnace is placed which receives the cast iron; it can be closed by removable covers of refactory material and is provided with two electrodes the position of which is adjusted by hand.

When the operation begins, the materials to be treated are fed into the shaft at the top of the furnace. In order to observe the condition of the separate high temperature zones at the end of each of the four electrodes, four ammeters are provided, one in the circuit of each electrode, and two voltmeters; the regulation is then accomplished by a movement of the electrodes. The fusion and reduction of the ore starts at the bottom of the furnaces. The gases developed rise to the upper part of the furnace and are then burned in a suitable chamber, in order to utilize the heat for drying fresh material to be fed into the furnace.

After several hours, the molten metal is drawn off into the lower furnace which has been previously heated and already contains fused materials. When the metal has been drawn off from the upper furnace down to the slag, the tapping hole is closed, and new material is fed at the top into the upper furnace. After a certain time the slag of the upper furnace is discharged through an opening provided for this purpose in the side of the furnace. The slag and the metal are examined at regular intervals, and it is possible to obtain a metal of absolutely uniform composition.

When the lower furnace contains a sufficient quantity of liquid metal, the process of refining is started; the current is so adjusted as to accomplish perfect liquidation and rapid reaction of the metal with the refining and purifying agents.

Mr. Bertolus remarks that the rough metal may be decarburized either by adding oxide to the bath, the oxide added being the iron ore itself, or by the addition of scrap iron. The purification is brought about by a suitable addition of lime. Samples are taken at regular intervals, to determine the stopping point of the process of decarburizing and purification. The further treatment seems to be the same as in the ordinary metallurgical process.

Mr. Keller, who is personally in charge of this process, remarks that on account of the relatively small amount of power at this point, it was not thought to be advisable to install certain additional improved apparatus devised by him for the manufacture on a large scale. He claims that his new apparatus would enable him to cast and refine quantities of steel of 15 to 20 tons at the same time, or even more if necessary. Mr. Bertolus states that he was also present when the process of making steel from scrap iron was worked; this process requires somewhat different electrical conditions.

The principal point is, of course, the cost of the process, and for this reason we give herewith a literal translation in full of the portion of Mr. Bertolus' paper, dealing with the cost of the process. The figures given are, of course, based upon the conditions in France; we have changed the figures from French into American money, 5 francs being assumed to be one dollar.

"We have verified that the manufacture of one ton of steel

require 2,800 effective kilowatt hours, say, about 3,800 electric horse-power hours. To determine the cost in the case of the direct treatment of the ore, we assume as a basis the following prices which are taken from ordinary practice:

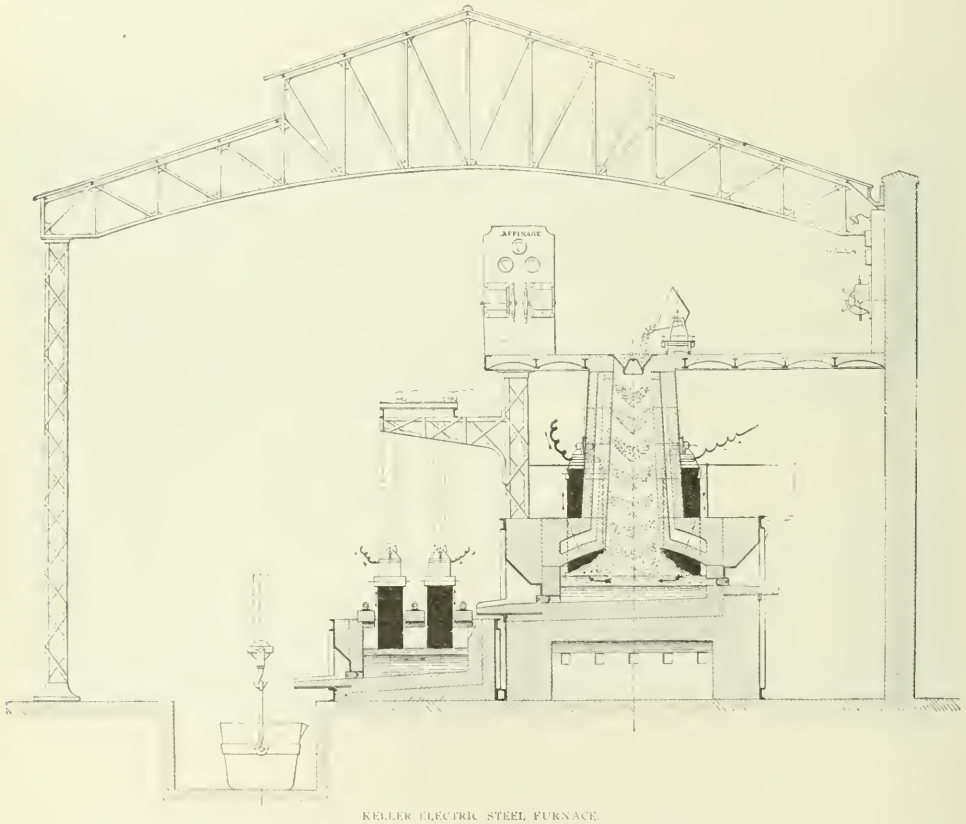
| | |
|---|---|
| One ton of iron ore, containing 55 per cent. of iron, delivered at the plant | $2. |
| One ton of coke for reduction, delivered | 8. |
| One ton of flux, delivered | 3. |
| Price of labor per day | 0.60 |
| 100 kilograms of electrodes, delivered | 6. |
| Electrical energy, per kilowatt year of 8,400 hours | 10. |

This last price includes depreciation of the buildings and of the machinery. In the case of a plant of average size, the cost of manufacture of a ton of steel includes: 1. Raw materials (ore, coke, electrodes, fluxes, and special materials). 2. Electrical energy. 3. Labor. 4. Maintenance (maintenance in general, ingot moulds, refactory materials, tools). 5. General current expenses. 6. Deterioration; and the total cost* may be assumed to be about $18.

One may therefore conclude that the ton of steel made by the electric treatment direct of the ore and cast into ingots, not including the license of manufacture, can be made at a cost of $18 to $20, in round figures. For exceptionally low prices of raw materials and electrical energy the cost of manufacture could be, of course, diminished."

In the manufacture of steel from scrap iron, the output of a furnace is greater for the same power, than in the manufacture of steel direct from the ore; hence the electrical energy enters into the cost of one ton of steel as a less important item in the first case than in the second. On the other hand, in the cost of manufacture of one ton of steel, the scrap iron represents generally a larger item than the ore and the coke together. Whether the one method is superior to the other, depends therefore only on the geographical situation of the plant.

Concerning the quality of the steel produced in the Keller furnace, Mr. Bertolus reproduces extracts from a report on tests made with an ingot of this steel by the metallurgists of the Basin de la Loire. He concludes that the quality of the ordinary steel made in the electric furnace is fully satisfactory to metallurgists; the electric steel can enter into competition with the Martin (open hearth) and Bessemer steel. As in




KELLER ELECTRIC STEEL FURNACE.

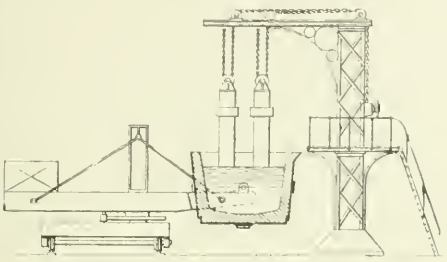
the electric furnace the heat produced is not due to an oxidizing agent, the steel which is made electrically is less liable to contain oxides of iron in solution and it can easily reach the quality of crucible steels. Moreover in comparison with the crucible process, the manufacture of steel in the electric furnace has the great advantage that it can be undertaken on a much larger scale and "it is absolutely certain that very soon the small crucibles containing 30 kilograms of steel which are at present used in the large metallurgical plants, will be replaced by large electrically-operated crucibles containing several thousands of kilograms of metal."

This is essentially the contents of Mr. C. Bertolus' interesting paper. We are indebted to Mr. P. McN. Bennie for the following additional information on improved apparatus

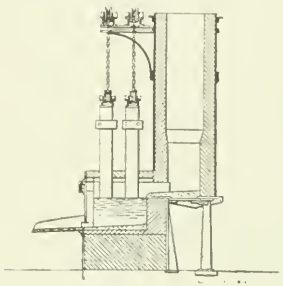
* Presumably per metric ton, *i. e.*, 1000 kg. or about 22.0 pounds.

recently designed by Mr. Keller and shown in two adjoining diagrams. The one shows an arrangement in which the refining furnace is mounted upon a truck running on rails, so that it may be moved along a series of electric furnaces; the one refining furnace thus serves the whole series and is therefore almost in constant use, the economy of the process being thereby increased. The other diagram shows an arrangement in which the refining furnace is operated in conjunction with the ordinary foundry cupola.

Mr. P. McN. Bennie points out that the problem should



LADLE FURNACE.



CASCADE FURNACE.

be of great interest to American metallurgists in view of the great water-power developments in the neighborhood of the Lake Superior ore deposits, and of the titaniferous iron ores in New York State and Canada. On the other hand, he calls attention to the fact that the application of electric-furnace methods is not restricted to regions with water power. The blast-furnace gases may be utilized for driving gas engines coupled with electric generators, so that the electric-furnace process might be worked in conjunction with blast furnaces.

## SOME LABORATORY OBSERVATIONS ON ALUMINIUM.

By Prof. C. F. Burgess and Carl Hambuechen.

WHILE Nature has rewarded modern ingenuity and enterprise in giving to mankind one of her most important treasures, she has withheld much of the knowledge relative to this important metal which is necessary in order that it may be utilized to greatest advantage.

Aluminium having become a material of every-day use, our familiarity with it is conducive to the idea of intimate acquaintance. That we are not thoroughly acquainted with it, however, is shown by the very contradictory and misleading statements made in all sincerity, even by leading authorities, relative to the properties of this metal. But it cannot appear strange that our knowledge of this metal is deficient when a thorough study reveals the fact that we really know little about the oldest and most important structural metal—iron.

Each addition to our knowledge of the properties of aluminium points the way for new applications of the metal, and the extent of its use in the future can be judged best by estimating the increase of knowledge regarding its properties. The adaptability of aluminium for a new and previously untried use can be estimated best if not alone by actual trial. Experience is, particularly in this case, the best teacher, for what reliance could be placed upon advice such as that of which the following statements quoted from authorities of note give a common illustration? "Aluminium is unaffected by either sulphuric or nitric acids," and "Sulphuric and nitric acids act immediately upon aluminium."

There are certain properties of this metal which, while known by some for a long time, have not become matters of general information. It is the purpose to point out in this paper a few such features, and to give data and results of observations made in the laboratory of applied electrochemistry of the University of Wisconsin during the past two years. Some of these observations are both contradictory and confirmatory of previously published statements, and certain other observations, it is believed, are pointed out here for the first time.

The properties which are especially peculiar to aluminium are, in some cases, obstacles which have to be encountered and overcome in adapting the metal to certain uses, and in other cases these same properties are the ones which enable the metal to be employed for purposes that no other metal can fulfill.

Aluminium has not been used for a sufficient length of time to enable certain properties, such as corrodibility under various atmospheric conditions, to be determined. It is called by some a very corrodible metal, and by others a very durable substance, depending perhaps upon the point of view, whether theoretical or practical. Theory might indicate that aluminium occupying an electropositive position in the electrochemical series of elements may be expected to become oxidized or acted upon by an oxidizing agency with much greater readiness than all the other common metals, and this is borne out in the Goldschmidt reducing process, where aluminium, in a finely divided form, is used as a strong reducing agent. Further, if an aluminium plate be thoroughly amalgamated and exposed to the air, it will oxidize so readily as to form in a few minutes a thick, white, voluminous layer of aluminium oxide, and the plate will become so hot as to be uncomfortable to the hand. There are no other common metals which will "burn up" so readily when placed in contact with the air.

We have, on the other hand, however, the fact that this metal may be placed in contact with either dilute or concentrated nitric acid and the corrosive action will be extremely slow, and with sulphuric acid it will also be so slow as to escape detection unless observed for a considerable length of time. Inasmuch as aluminium will resist the oxidizing action of these strongest oxidizing agents, in a degree which none of the other metals, with the exception of gold and platinum, can equal, there has been some ground for the statements that aluminium behaves as a noble metal, and can be used for the cathode of a primary battery.

Many of such contradictory conclusions regarding aluminium may be based upon such factors as the use of impure aluminium in one case and aluminium of a high degree of purity in another, differences of temperature and various other considerations, including perhaps the most important of all, the well known supposition that aluminium is covered with a thin, invisible protective film, which, under certain conditions, effectually prevents contact of the metal itself with the air, solution or other surrounding influences wherever such surrounding influences are not such as to destroy this coating. This film is supposed to have considerable strength and continuity, and if it is broken or removed by mechanical means the aluminium immediately forms a new one. If, therefore, this metal could be used as a structural material for bridges,

the maintenance of such structures would not involve an annual expenditure for painting, since they would "paint themselves."

There has been some difference of opinion as to whether such protective coating really exists, and, if so, whether it is that which influences or determines the apparent properties of the metal. It is true that the coating must be very thin; it can barely, if at all, be detected by the microscope, and it is impossible to collect enough of it for determination of composition by chemical analysis. It is variously held to be a continuous coating of aluminium oxide, or a basic compound, or a hydroxide, etc. The chemical composition has never been determined with any degree of assurance. Suffice it to say that experimental evidence seems to prove that such film exists, and some of the facts bearing on this point will be referred to in the following.

Among the problems which have received much attention, and the satisfactory solution of which has an important bearing upon the extent of the utilization of the metal, are the soldering, the electrodeposition of various metals upon aluminium and the electrodeposition of aluminium upon other conducting surfaces.

Aluminium alloys readily and through a wide range of proportions with other metals, a fact which might naturally point to the conclusion that the soldering of aluminium should be an easy matter, as should also the deposition of other metals upon its surface. Practice has shown, however, that success can be attained only by most careful operation. The principal difficulty in soldering aluminium seems to be due to the failure of the alloy used as a solder to adhere to the aluminium, a condition attributable to the protective film, which must be eliminated before the metals can unite. A great many suggestions have been made and processes patented for doing this work, although only a few have proved practical. The various methods may be classified in the divisions: those using a flux; those employing a special solder which works its way over the surface without a flux, and those depending upon the mechanical abrasion or cleaning of the surface while the solder is being applied. Combinations of the above may also be used.

The higher the temperature to which aluminium is heated, the greater is the ease with which the solder will unite, and by heating to the softening point and scratching the surface almost any solder which will melt at that temperature will flow over the aluminium surface. Possibility of damage to the aluminium article, together with the inconvenience of working at this high temperature, makes such process impracticable for most purposes, and it is really a welding rather than a soldering process.

It has been found that certain solders, properly proportioned and compounded, can be applied to aluminium quite readily without the use of a flux, and at a temperature such that the ordinary soldering copper can be used. The "tinning" of the surface is facilitated by mechanical abrasion while the solder is being applied. Of the various metals entering into the composition of such solders, the most important are zinc, tin, aluminium, lead, nickel, copper and bismuth. Just what functions the different ingredients fulfill is perhaps unknown. It may be that certain metals give to the solder the ability to work its way or flow by capillarity or otherwise under the surface film on the aluminium, and thus alloy with the metal. Zinc seems to possess this property to the most marked degree.

A successful solder of this sort, which is now on the market and in quite extensive use, has a composition something as follows: Zinc, 21 per cent.; tin, 76 per cent., and aluminium, 3 per cent. This may be applied directly to a cleaned aluminium surface without the use of a flux, and at a temperature but little above that which is necessary for soldering copper or iron.

There are certain advantages in the apparent complication which the use of a flux involves. A suitable solvent for the oxide film increases the rapidity of the soldering process, increases the certainty of adhesion and enables cheaper soldering mixtures to be employed. The requirement for such a flux is that it should dissolve the coating and leave a clean surface for the solder to unite with upon application of heat. While there are various aqueous solutions, such as hydrochloric acid, hydrofluoric acid and ammonium fluoride, which are solvents for the aluminium coating, none of these substances will leave a clean surface after the application of heat. The results of a large number of tests with different materials seem to point to the fact that water cannot be a component of a suitable flux. Following this idea, a flux was made up by means of which any ordinary solder, such as 50 per cent. tin and 50 per cent. lead, may be made to readily unite with an aluminium surface which had not been previously cleaned. Such material contained potassium fluoride as the principal ingredient, potassium fluoride and resin being dissolved in acetone and a little zinc chloride added to harden the mixture. By exposure to the air, a partial solidification takes place, the resultant pasty substance being in a form suitable for a flux.

Another material which, for certain solders, forms an admirable flux is stearic acid. By applying this to a freshly-scraped aluminium surface, and then applying a tin-lead-zinc alloy, the matter of soldering aluminium presents scarcely greater difficulties than does the soldering of other metals.

This almost ever-present coating upon aluminium is the source of difficulty in the deposition of a permanent coating of other metals upon aluminium surfaces. Although aluminium itself presents a surface to atmospheric conditions which ordinarily needs no further protection by other metals and maintains a pleasing appearance, still there are many cases where it is desirable, for ornamental and protective purposes, to apply to it a durable coating of other metal. Aluminium continually coming in contact with the hands, and subjected thereby to the action of the perspiration, undergoes corrosion somewhat rapidly. A certain instance has come to the writers' attention where an aluminium handle on a certain form of tool corroded so rapidly as to become useless in a few weeks. The advantage of a protective coating of some other metal is, in this instance, evident, and many other similar cases might be cited. There is also a growing demand for gold and silver plating on aluminium objects, such as toilet articles, tableware, ornaments, etc., and a cheap and successful method of performing this operation will be of advantage to the aluminium industry.

The obstacles in this matter are, first and last, the difficulty in electrodepositing a metal which will stick. While it is a very simple matter to deposit a layer of metal upon aluminium from almost any plating solution, in the great majority of operations the resulting coating can be readily removed; sometimes in remarkably thin and continuous layers, and it is only by observing certain precautions that the resultant coating will stand the buffing or polishing operations. The writers have employed aluminium plates in the production of thin sheets of zinc, nickel and other metals, such metals, after being deposited to a desired thickness, having been separated from the aluminium by means of air pressure. Even though the coating may apparently adhere and stand the buffing operation without blistering, the success of the coating is not insured; subsequent exposure to moisture may cause the coating to become loose, or, even if no external moisture be present, the solution which may have been inclosed in the pores of the metal may spread out and cause separation of the coating.

The prime requisite in successful deposition on aluminium is the complete removal of the protective film, so that the electrodeposited metal may be applied over the complete surface of and in intimate contact with the aluminium. If this condition is fulfilled and the coating is non-porous, it will be durable.

Various formulas for carrying out this operation have been published and patented, and, while the majority of them are unsuccessful and misleading, there are certain methods of procedure through which successful results may be attained. The limits of this paper, however, do not allow a discussion of the

various processes which may be employed. As a result of laboratory investigation, it has been found that the deposition of metals upon aluminium can be carried out with the same ease, and with practically the same durability of results, at least as far as tests covering one year's time would indicate, as upon iron and other metals.

The converse of this operation, however, the electrodeposition of aluminium upon other metals, is an entirely different matter. The desirability of performing this operation has long been recognized, and has led to much experimental investigation on the deposition of aluminium from aqueous solutions, the principal object being to make the corrosion-resisting properties of aluminium available in the protection metal surfaces from corrosion, thus affording a more efficient protection than tinning or galvanizing, as now applied. Such process has not as yet shown any signs of development, although statements have been made from time to time since the discovery of aluminium that success had been attained in the deposition of aluminium from aqueous solutions, some of these statements having been contributed by men of note in the scientific world. Whether we shall conclude that such statements have been purposely misleading or made as a result of erroneous conclusion, and explain the fact that no electrolytic aluminium plating has been exhibited for public inspection because secrecy has to be maintained in regard to it, the fact is that this process has shown no outward signs of commercial success. A method of depositing aluminium from aqueous solutions would find application not only for ornamental and protective purposes, but, if such a process had been discovered, it would be heralded as a means for obtaining aluminium from its compounds.

While there do not seem to be any laws of nature which prohibit the deposition of aluminium from aqueous solutions, and while it is not beyond the range of possibility that a suitable means for doing it may be discovered, the probability is that a solution other than an aqueous one must be used. Evidence seems to point to a fact that where water is present the deposition of aluminium is prevented.

The adaptability of aluminium for electrode purposes has received some attention at the hands of electrochemists. There are certain limitations which make it unsuitable for most electrolytic operations. When used as the cathode, the tendency of the reducing action and of the gases liberated is to remove the protective film, and thus cause continual exposure of the plate to the solution and its consequent corrosion. In aluminium we have one of the few instances where the cathode is corroded, and in some cases the results are quantitative and in close agreement with the requirements of Faraday's laws.

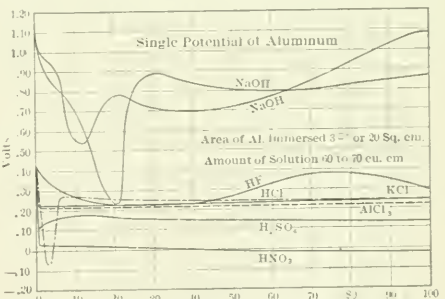
The fact that aluminium separates readily from a metal which has been electrolytically deposited upon it may be utilized to advantage in certain cases. It has been proposed to use this metal for cathodes in the electrolytic recovery of gold from cyanide solutions, the gold being easily collected as soon as a sufficient thickness has been attained, thus avoiding a smelting operation, as where lead cathodes are employed.

Aluminium as an anode frequently presents striking characteristics, due to the fact that the oxidizing action at the anode in many solutions tends to increase the durability and insulating power of the protective coating, with the result that the current may be entirely interrupted, even if a high pressure be applied. This coating has the property also of freely allowing current to flow from the electrolyte to the electrode although not in the reverse direction, and the effectiveness with which this operates enables it to be used as an efficient check valve for the electric current, making it possible, among other uses, to obtain a unidirectional current from alternating current circuits.

If two aluminium plates be placed in a sodium potassium tartrate solution, and an alternating pressure of about 50 volts be applied, a view of the plates in a dark room will show a distinct phosphorescence; an increase of pressure causes an exceedingly beautiful sparkling, which, on close inspection, bears a resemblance to the appearance of the heavens on a clear night, with even an imitation of the milky way; and a further increase of pressure causes a more marked sparkling effect of great brilliancy, and the possibility of adapting this phenomenon to advertising and display purposes at once suggests itself. This appears especially practical when an examination of the electrical instruments show that a very small amount of energy is necessary in producing a considerable degree of illumination, and the impression which is obtained from a bright illumination under water is sufficiently startling to be attractive.

Another way in which aluminium may play an important part in an electrochemical manner is in its use as the metal to be consumed in a primary cell for the production of electrical energy.

From the fact that, for equal weights, aluminium possesses about four times the energy as does zinc, some considerable attention has been given the matter of substituting the former metal for the zinc commonly used in primary cells or electrochemical generators of electrical energy, and various patents have been granted on means for accomplishing this. Aluminum, being a more electropositive element than zinc, might be expected to give, in combination with suitable cathode and electrolyte, a higher electromotive force than does zinc under similar circumstances. The present price of aluminium places that metal on something of a par with zinc, as far as cost of




POTENTIAL CURVES OF AN ALUMINIUM ELECTRODE.

generation of electrical energy is concerned, and the higher electromotive force and greater lightness of aluminium make it a desirable material for battery purposes when considered from the theoretical standpoint. As a matter of fact, however, aluminium does not behave well as the electropositive metal of a battery and attempts to use it in practice have almost universally failed. Its failure to give the results which might be expected can again be attributed to the partially insulating compound which forms on the aluminium surface.

The conditions under which aluminium sets up and maintains the highest values of electromotive force, together with various other factors concerning this metal, is the subject of investigation which is being carried on in our laboratory by Mr. W. R. Mott. The accompanying tables and curves derived therefrom give some of the values determined by him. These show some interesting facts concerning the behavior of aluminium in various electrolytes.

The values of single potentials here given are based upon the normal "calomel" electrode the potential of which is assumed as + 0.56 volt. By measuring between this electrode and the aluminium in contact with the respective electrolyte and deducting the value of the normal electrode, the value of single potential of the aluminium is determined.

The measurements were made as follows: Strips of aluminium, about 3 inches long and ½ inch wide, were cut from an aluminium sheet just as obtained from the factory. Without any preliminary cleaning or special treatment, they were immersed in their respective solutions, and a reading of potential made immediately after immersion. The strips were then

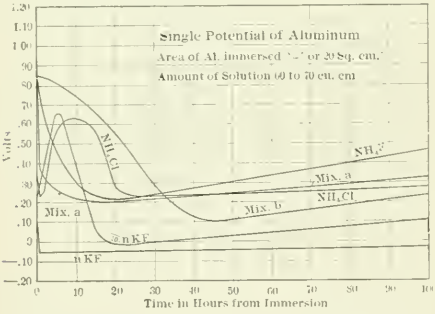
left in the solutions for about one hundred hours, and readings of potentials made at intervals during that time.

TABLE OF SINGLE POTENTIALS OF ALUMINIUM IN VARIOUS ELECTROLYTES.

| Time in hours | | 0 | .5 | 1.5 | 5.0 | 6.2 | 21.6 | 27.9 | 77.9 | 99.9 |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Solution. | Volt | Volt. | Volt. | Volt. | Volt. | Volt. | Volt. | Volt. | Volt. |
| 1. | KCl | .470 | .226 | .226 | .226 | .227 | .220 | .235 | .232 | .250 |
| 2. | AlCl | .382 | .235 | .220 | .220 | .310 | .211 | .220 | .220 | .220 |
| 3. | AlCl | .361 | .211 | .205 | .211 | .250 | .199 | .220 | .214 | .217 |
| 4 | HCl | .460 | .256 | .062 | .211 | .271 | .250 | .250 | .232 | .232 |
| 5. | $H_2SO_4$ | .400 | .121 | .130 | .151 | .220 | .169 | .150 | .130 | .130 |
| 6. | HNO | .220 | .040 | .040 | .040 | .040 | −.023 | .010 | .032 | −.017 |
| 7. | NaOH | 1.120 | 1.000 | .964 | .889 | .769 | .790 | .721 | .925 | 1.090 |
| 8. | NaOH | 1.147 | .976 | .913 | .826 | .895 | .220 | .880 | .820 | .874 |
| 9. | HF | .430 | .382 | .397 | .238 | .250 | .229 | .225 | .370 | .289 |
| 10. | $NH_4Cl$ | .367 | .212 | .274 | .580 | .610 | .235 | .232 | .250 | .310 |
| 11. | $NH_4F$ | .925 | .616 | .895 | .556 | .211 | .217 | .370 | .400 | .454 |
| 12. | KF | .010 | −.050 | .053 | −.023 | −.023 | −.068 | −.008 | −.026 | −.053 |
| 13. | KF | .223 | .346 | .445 | .652 | .610 | .026 | .022 | .100 | .040 |
| 14. | Mix. *a* | .925 | .370 | .310 | .280 | .250 | .220 | (*) | .274 | .262 |
| 15. | Mix. *b* | .760 | .550 | .820 | .790 | .778 | .520 | .286 | .187 | .235 |

(*) On allowing current to flow, potential rose from .220 to .403 volt.

Solutions 1, 4, 5, 6, 7, 9, 10, 11 and 12 were normal solutions; 2 was dilute solution of aluminium chloride, commercial; 3, dilute solution of pure aluminium chloride; 8 was 0.1 normal solution of sodium hydroxide; 13, a 0.1 normal solution of potassium fluoride; 14, a mixture of equal parts of normal ammonium chloride and normal ammonium fluoride; 15 was a mixture of normal ammonium chloride and 0.1 normal potassium fluoride.




POTENTIAL CURVES OF AN ALUMINIUM ELECTRODE.

From the first column of values, it will be noted that the potential of aluminium at the moment of immersion in various electrolytes has widely different values, depending upon the solution employed. The lowest value here given is 0.01 volt in potassium fluoride, and the highest 1.147 volts in sodium hydroxide.

The data here given would point to the conclusion that, of the various materials tested, ammonium fluoride would be the best material to use in connection with aluminium for battery purposes, the use of this being analogous to the use of ammonium chloride in connection with zinc in the ordinary type of open-circuit cell. Tests which were made showed that an aluminium-consuming cell of this type would set up a pressure of almost 2 volts. The factors governing commercial operation, such as constancy of pressure on open and closed circuit, the consumption of aluminium and electrolyte, polarization, etc., have not been completely investigated.

It will be noted, from measurements taken at intervals covering a period of one hundred hours, that the general tendency is for the single potential to decrease, though there are instances when the pressure increases to some degree. The variations are shown in the curves, some of which exhibit marked irregularities, which may indicate certain properties of the metal, or they may have been accidental, the results of errors of observation or other factors. An investigation of such irregularities is the subject of further investigation.

Aluminium shows greater variations in its contact potentials with different solutions than perhaps any other metal. Chromium has been shown to exhibit three widely different values of single potential, depending upon different stages of oxidation which it may undergo, it being capable of combining in three different valencies. A similar assumption in the case of the variations in the single potentials of aluminium can hardly hold, and the explanation must be sought elsewhere. One such is that in certain cases, those in which we obtain the highest values, it is the potential of the metal itself which is being determined. In other cases it may be that the aluminium, wherever its protective coating is fractured or perforated so as to allow its coming in contact with the solution, coats itself with a layer of hydrogen, and it is really the single potential of hydrogen which we are measuring. Or, further, the aluminium coating may itself set up a single potential, being a conductor of sufficient conductivity to allow the measurement being taken, and there seems to be some evidence pointing to different kinds of coatings in different solutions.

The influence of the protective coating which normally exists on aluminium, after exposure to the air, is shown in the curve for ammonium chloride. The potential upon immersion is low, then rises for several hours, indicating a very slow dissolving action of the solution upon the coating, and then the potential gradually falls. The maximum point in the curve comes very much quicker, as shown in curve for mixture *b*, No. 15, where a small amount of potassium fluoride, a partial solvent for the coating, was present. With mixture *a*, No. 14, the solvent action of the ammonium fluoride was so great as to cause the aluminium to assume its maximum value of potential immediately upon dipping in the solution.

The data here given shows a number of notable peculiarities, one being the fact that aluminium in contact with the normal potassium fluoride solution gave a much lower value, at least for the first half of the time, than did the one-tenth normal solution of the same salt. A change of concentration, with a solution of ammonium nitrate from 0.018 normal to 4.66 normal, produced a difference of only 0.1 volt, and the change of value did not seem to be a function of the concentration.

It is possible that some of these peculiarities may be explainable on errors of observation, or they may be due to different physical condition of the aluminium samples, although care was taken to cut all the pieces tested as nearly of a size as possible from an aluminium sheet and subjecting them all to similar treatment. That the physical condition of the aluminium may exert a large influence was shown by measuring the potential of an aluminium strip as cut from the sheet and again measuring it after having been hammered between aluminium plates. Differences of potential of considerable amounts were thereby produced.

The temperature is another factor which may play an important part. A rise in temperature causes a large increase of pressure in some cases and a much smaller one in others, and it may even cause a decrease in the value of the single potential.

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Cleveland as a Center in Electrochemical Development.—We have received a small pamphlet containing a reprint of a recent article by Mr. Cecil L. Saunders in *Electrical World and Engineer*.

The article is a review chiefly of the work done with the electric furnace by the Cowles brothers, although later developments are also mentioned. In a general way, the application of the electric furnace to various metallurgical processes is sketched.

Some historical and personal notes are added. From the data given, it is interesting to note how many of our most successful electrochemical engineers were formerly in some way connected with Cleveland. No detailed technical information is given in the pamphlet on the processes which are mentioned.

## TABLE OF ELECTROCHEMICAL EQUIVALENTS AND THEIR DERIVATIVES.

BY CARL HERING.

In view of the more accurate determinations of the atomic weights and of the electrochemical equivalent of silver which have recently been made, and are now adopted almost universally, the electrochemical equivalents of all the elements which are likely to occur in practice or in experimental research have been recalculated on the above bases under the direction of the writer, and the results are given in the accompanying table, together with many of their derivatives. The table contains not only the data generally given in other tables, but many other elements and valencies in addition, besides a number of new columns which will often be found very useful.

The atomic weights used as a basis are those given in the eighth annual report of the Committee on Atomic Weights of the American Chemical Society, published by the well known authority F. W. Clarke in the journal of that Society for February, 1901. The values are those generally adopted by chemists in this country. They differ but very slightly from the standard values adopted in Germany, many being, in fact, identical. The atomic weights given in this table are for oxygen = 16, and not for hydrogen = 1, as the former are more generally used; but the electrochemical equivalents and their derivatives are, of course, independent of these arbitrary bases, and are therefore exactly the same for both. The only alteration made by the present writer in these values of the atomic weights was to change that of silver from 107.92 to 107.93. The latter conforms with the German table and that of T. W. Richards, and is probably the more accurate; but the chief reason for making this very slight change is that the value 107.93, when taken together with the international standard value of the electrochemical equivalent of silver, 0.001118 grams, gives 96,538.5 coulombs for the ionic charge per unit valent gram ion, and this is in practical agreement with the abbreviated value 96,540, which is so commonly used in all countries. The adoption of 107.93, instead of 107.92, for the atomic weight of silver therefore makes the agreement between some of the different units used by electrochemists almost absolute, and is therefore thought to be justified. As the difference between 107.93 and 107.92 is only 1 100 of 1 per cent., it is, moreover, absolutely negligible in almost all cases.

The other fundamental value used in this table is the electrochemical equivalent of silver, namely, 0.001118 gram per coulomb, which was adopted by the International Electrical Congress, at Chicago, in 1893.

The value of the ionic charge which necessarily results from these two fundamental values is 96,538.5 coulombs per unit-valent gram ion, which is in practical agreement with the abbreviated value 96,540 in common use, the difference involving only unwarranted accuracy.

The column containing the valencies has also been headed "change of valency." The reasons for this will be explained below. It will suffice to say here that the latter term is the rational and more accurate way of stating that which concerns the electrochemist, and it simplifies many of the calculations. Every quantitative calculation of electrolytic action involves a change of valency, or a difference between two valencies, while only certain ones (though perhaps the majority in ordinary practice) involve directly the whole of the valency itself. It is for this reason that this column contains some numbers which may never occur as valencies, but which do occur as changes of valency. For the ordinary and more usual case of the setting free of an element (such as a metal or gas) at the electrodes, the change of valency and the valency itself are the same thing, as the valency of a free element is zero, and in such cases either term is correct. In many cases the equivalents for a change of valency equal to unity have been added, so that those for any other changes of valency may then be easily calculated by mere multiplication or division by a single digit. The formulas at the end of the table give the reduction factors for calculating the electrochemical equivalents and their derivatives for any other atomic weight or changes in valency than those given in the table. For instance, if $n$ is the equivalent given in any one of these columns for a valency $a$, then for a different valency $b$ this number $n$ must be multiplied by either $(a \div b)$ or by $(b \div a)$, as indicated. This is always a very simple calculation, as the valencies are always simple digits. The last line gives the factors with which any of these electrochemical equivalents can be calculated for any element, the atomic weight (for $O = 16$) being represented by $y$ and the valency by $x$.

The last eight columns also give the energy equivalent per volt, from which the energy may be determined directly for any other voltage by merely multiplying or dividing by that voltage. These numbers, of course, can be used equally well with the theoretical as with the actual voltage to calculate the theoretical or the actual energy respectively. The value for the horse-power which was used in the last four columns is 745,050 watts, which is the latest and best value obtainable.

In all cases the reciprocal values are also given, so that every calculation can be made by a multiplication as distinguished from a long division. Many of the values are given to a greater accuracy than would be justified by the original data, as the first two or three left-hand figures suffice for most calculations. The object of this accuracy is to enable new values to be determined by mere proportion for any more accurate or different values of the atomic weights that may be found in the future or may be preferred. The electrochemical equivalents and their derivatives, as given in the table, are exactly correct for the values of the atomic weights there given, excepting, of course, the usual slight inaccuracy of the last right-hand digit. The calculations have been made very carefully to five and six places of figures, and were subsequently checked. It is therefore believed there are no errors. Should, however, any errors be discovered, the writer will be greatly obliged if the correction be sent to this journal, as it is the intention to make this table a standard one.

### APPLICATION OF THE TABLE.

A correct knowledge of what the valencies are is of the utmost importance. The amount of copper deposited per ampère hour from a cuprous solution, for instance, is just twice as great as that from a cupric solution, because the valency is half as great in the former and the amount per ampère hour is inversely proportional to the valency. How to find what the valency is will be described later.

The following examples will serve to illustrate the application of the table; they also serve as typical methods of solving more or less difficult problems involving Faraday's law:

*Simplest Case: Deposition or Solution.*—The valency of any element in its free, uncombined state is assumed to be always zero, hence when an element is set free electrolytically the change of valency which it has undergone is always equal to the whole valency. These are the simplest cases to calculate, and include the majority occurring in ordinary practice, as what one generally desires to know is how much metal, gas, etc., will be set free from its solution or dissolved per ampère hour. In such cases all that is necessary is to find out what the valency of that element is in the electrolyte, then look for it in column 2 of the table, and the desired electrochemical equivalent or derivatives from it will then be found to the right in one of the different columns.

*Example.*—How many grams of silver will be deposited in a silver voltameter by 5 ampère hours? The electrolyte is always nitrate of silver, $AgNO_3$, in which the valency of the silver is 1. In the table after Ag and valency 1, the figure under grams per ampère hour is 4.02, which, multiplied by 5, gives 20.10 grams.

How many pounds of zinc will be consumed (not including local action, of course) in the usual chromic acid battery for 10 available horse-power hours if the available voltage is 1.7?

# TABLE OF ELECTROCHEMICAL EQUIVALENTS

## AND THEIR DERIVATIVES.

| Symbol. | Valency, or change of valency. | Atomic weight; Oxygen = 16 (Clarke). | Milligram per coulomb. | Coulomb per milligram. | Grams per ampère hour, or Gr. per watt-hr. when ÷ by volts, or Klgr. per k.w.-hr. when ÷ by volts. | Ampère-hours per gram, or Watt-hrs. per gr. when × by volts, or K.w.-hrs. per klgr. when × by volts. | Pounds per 1,000 ampère hours, or Pounds per k.w.-hr. when ÷ by volts. | Ampère-hours per pound, or Watt-hours per pound when × by volts. | Kilograms per horse-power-hour when ÷ by volts. | Horse-power-hours per kilogram when × by volts. | Pounds per horse-power-hours when ÷ by volts. | Horse-power-hours per pound when × by volts. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Ag | 1 | 107.93 | 1.1180 | 0.8945 | 4.0248 | 0.24846 | 2.873 | 112.70 | 3.0011 | 0.33321 | 6.616 | 0.15114 |
| Al | 3 | 27.1 | 0.09357 | 10.687 | 0.33680 | 2.9686 | 0.7427 | 1346.5 | 0.25118 | 3.9812 | 0.5538 | 1.8058 |
| As | 1 | 75 | 0.7769 | 1.2872 | 2.7968 | 0.35753 | 6.166 | 162.18 | 2.0855 | 0.47951 | 4.5975 | 0.21750 |
| " | 3 | | 0.25896 | 3.8615 | 0.9323 | 1.0726 | 2.0553 | 486.55 | 0.6952 | 1.4385 | 1.5325 | 0.6525 |
| Au | 1 | 197.2 | 2.0427 | 0.48954 | 7.354 | 0.13599 | 16.212 | 61.68 | 5.483 | 0.18237 | 12.089 | 0.08272 |
| " | 3 | | 0.6809 | 1.4686 | 2.4513 | 0.40796 | 5.404 | 185.05 | 1.8278 | 0.5471 | 4.0296 | 0.24817 |
| B | 3 | 11.0 | 0.037981 | 26.329 | 0.13673 | 7.314 | 0.30144 | 3317.4 | 0.10196 | 9.808 | 0.22477 | 4.4490 |
| Ba | 2 | 137.40 | 0.7116 | 1.4052 | 2.5619 | 0.3903 | 5.648 | 177.05 | 1.9103 | 0.5235 | 4.2114 | 0.23745 |
| Bi | 1 | 208.1 | 2.1556 | 0.46390 | 7.760 | 0.12886 | 17.108 | 58.45 | 5.786 | 0.17282 | 12.756 | 0.07839 |
| " | 3 | | 0.7185 | 1.3917 | 2.5867 | 0.38659 | 5.703 | 175.35 | 1.9288 | 0.5185 | 4.2523 | 0.23517 |
| Br | 1 | 79.95 | 0.8282 | 1.2075 | 2.9814 | 0.33541 | 6.573 | 152.14 | 2.2231 | 0.44983 | 4.9011 | 0.20404 |
| C | 1 | 12.0 | 0.12430 | 8.045 | 0.44749 | 2.2347 | 0.9866 | 1013.6 | 0.33367 | 2.9969 | 0.7356 | 1.3594 |
| " | 4 | | 0.031076 | 32.179 | 0.11187 | 8.939 | 0.24664 | 4054.5 | 0.08342 | 11.988 | 0.18390 | 5.438 |
| Ca | 2 | 40.1 | 0.20769 | 4.8149 | 0.7477 | 1.3375 | 1.6484 | 606.7 | 0.5575 | 1.7937 | 1.2291 | 0.8136 |
| Cd | 2 | 112.4 | 0.5822 | 1.7178 | 2.0957 | 0.47716 | 4.6203 | 216.43 | 1.5627 | 0.6399 | 3.4451 | 0.29026 |
| Cl | 1 | 35.45 | 0.36721 | 2.7232 | 1.3220 | 0.7565 | 2.9144 | 343.12 | 0.9857 | 1.0145 | 2.1731 | 0.46016 |
| Co | 1 | 59.00 | 0.6112 | 1.6363 | 2.2002 | 0.45451 | 4.8506 | 206.16 | 1.6405 | 0.6096 | 3.6168 | 0.27649 |
| " | 2 | | 0.30558 | 3.2725 | 1.1001 | 0.9090 | 2.4253 | 412.33 | 0.8203 | 1.2191 | 1.8084 | 0.5530 |
| " | 3 | | 0.20372 | 4.9087 | 0.7334 | 1.3035 | 1.6168 | 618.5 | 0.5469 | 1.8287 | 1.2056 | 0.8295 |
| Cr | 1 | 52.1 | 0.5397 | 1.8530 | 1.9429 | 0.5147 | 4.2832 | 233.46 | 1.4487 | 0.6903 | 3.1938 | 0.31311 |
| " | 2 | | 0.26984 | 3.7059 | 0.9714 | 1.0204 | 2.1416 | 466.93 | 0.7243 | 1.3806 | 1.5969 | 0.6262 |
| " | 3 | | 0.17989 | 5.559 | 0.6476 | 1.5441 | 1.4278 | 700.4 | 0.48290 | 2.0708 | 1.0646 | 0.9393 |
| Cu | 1 | 63.6 | 0.6588 | 1.5179 | 2.3717 | 0.42164 | 5.229 | 191.25 | 1.7685 | 0.5654 | 3.8988 | 0.25649 |
| " | 2 | | 0.32940 | 3.0358 | 1.1858 | 0.8433 | 2.6143 | 382.50 | 0.8842 | 1.1309 | 1.9494 | 0.5130 |
| F | 1 | 19.05 | 0.19733 | 5.068 | 0.7104 | 1.4077 | 1.5661 | 638.5 | 0.5297 | 1.8879 | 1.1678 | 0.8563 |
| Fe | 1 | 55.9 | 0.5790 | 1.7270 | 2.0846 | 0.47972 | 4.5956 | 217.59 | 1.5544 | 0.6434 | 3.4268 | 0.29182 |
| " | 2 | | 0.28952 | 3.4540 | 1.0423 | 0.9594 | 2.2978 | 435.19 | 0.77718 | 1.2867 | 1.7134 | 0.5836 |
| " | 3 | | 0.19301 | 5.181 | 0.6949 | 1.4392 | 1.5319 | 652.8 | 0.5181 | 1.9301 | 1.1423 | 0.8755 |
| Gl | 2 | 9.1 | 0.047131 | 21.217 | 0.16967 | 5.894 | 0.37407 | 2673.3 | 0.12652 | 7.904 | 0.27892 | 3.5852 |
| H | 1 | 1.008 | 0.010441 | 95.77 | 0.037589 | 26.603 | 0.08287 | 12067. | 0.028028 | 35.678 | 0.06179 | 16.183 |
| Hg | 1 | 200.0 | 2.0717 | 0.48269 | 7.458 | 0.13408 | 16.442 | 60.82 | 5.561 | 0.17982 | 12.260 | 0.08157 |
| " | 2 | | 1.0359 | 0.9654 | 3.7291 | 0.26817 | 8.221 | 121.64 | 2.7806 | 0.35964 | 6.130 | 0.16313 |
| I | 1 | 126.85 | 1.3140 | 0.6478 | 4.7303 | 0.21140 | 10.429 | 95.89 | 3.5272 | 0.28351 | 7.776 | 0.12860 |
| Ir | 1 | 193.1 | 2.0002 | 0.4999 | 7.201 | 0.13887 | 15.875 | 62.99 | 5.369 | 0.18624 | 11.837 | 0.08448 |
| " | 3 | | 0.6668 | 1.4998 | 2.4003 | 0.41662 | 5.292 | 188.97 | 1.7898 | 0.5587 | 3.9458 | 0.25344 |
| K | 1 | 39.11 | 0.40512 | 2.4684 | 1.4584 | 0.6857 | 3.2153 | 311.01 | 1.0875 | 0.9196 | 2.3975 | 0.41710 |
| Li | 1 | 7.03 | 0.07282 | 13.732 | 0.26215 | 3.8145 | 0.5780 | 1730.2 | 0.19548 | 5.116 | 0.43095 | 2.3205 |
| Mg | 2 | 24.3 | 0.12586 | 7.946 | 0.45308 | 2.2071 | 0.9989 | 1001.1 | 0.3378 | 2.9600 | 0.7148 | 1.3426 |
| Mn | 1 | 55.0 | 0.5697 | 1.7553 | 2.0510 | 0.48757 | 4.5216 | 221.16 | 1.5293 | 0.6539 | 3.3716 | 0.29660 |
| " | 2 | | 0.28486 | 3.5105 | 1.0255 | 0.9751 | 2.2608 | 442.31 | 0.7647 | 1.3078 | 1.6858 | 0.5932 |
| " | 3 | | 0.18991 | 5.266 | 0.6837 | 1.4627 | 1.5072 | 663.5 | 0.5098 | 1.9617 | 1.1239 | 0.8898 |
| Mo | 2 | 96.0 | 0.49721 | 2.0112 | 1.7900 | 0.5587 | 3.9462 | 253.41 | 1.3347 | 0.7492 | 2.9425 | 0.33985 |
| N | 1 | 14.04 | 0.14543 | 6.876 | 0.5236 | 1.9100 | 1.1543 | 866.4 | 0.39039 | 2.5615 | 0.8607 | 1.1619 |
| " | 3 | | 0.048478 | 20.628 | 0.17452 | 5.730 | 0.38475 | 2599.1 | 0.13013 | 7.685 | 0.28689 | 3.4856 |
| Na | 1 | 23.05 | 0.23876 | 4.1882 | 0.8596 | 1.1634 | 1.8950 | 527.7 | 0.6409 | 1.5602 | 1.4130 | 0.7077 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ni | 1 | 58.70 | 0.6080 | 1.6446 | 2.1890 | 0.45684 | 4.8258 | 207.22 | 1.6322 | 0.6127 | 3.5984 | 0.27790 |
| " | 2 | | 0.30402 | 3.2892 | 1.0945 | 0.9137 | 2.4129 | 414.43 | 0.8161 | 1.2253 | 1.7992 | 0.5558 |
| " | 3 | | 0.20268 | 4.9338 | 0.7297 | 1.3705 | 1.6086 | 621.7 | 0.5441 | 1.8380 | 1.1995 | 0.8337 |
| O | 1 | 16.000 | 0.16574 | 6.034 | 0.5967 | 1.0760 | 1.3154 | 760.2 | 0.44489 | 2.2477 | 0.9808 | 1.0196 |
| " | 2 | | 0.08287 | 12.067 | 0.29833 | 3.3520 | 0.6577 | 1520.5 | 0.22245 | 4.4954 | 0.49041 | 2.0391 |
| Os | 2 | 191.0 | 0.9892 | 1.0109 | 3.5613 | 0.28080 | 7.851 | 127.37 | 2.6555 | 0.37658 | 5.854 | 0.17081 |
| P | 1 | 31.0 | 0.32112 | 3.1141 | 1.1560 | 0.8650 | 2.5486 | 392.37 | 0.8620 | 1.1601 | 1.9003 | 0.5262 |
| " | 3 | | 0.10704 | 9.342 | 0.38534 | 2.5951 | 0.8495 | 1177.1 | 0.28733 | 3.4803 | 0.6335 | 1.5787 |
| Pb | 1 | 206.92 | 2.1434 | 0.46655 | 7.710 | 0.12960 | 17.011 | 58.79 | 5.754 | 0.17380 | 12.685 | 0.07884 |
| " | 2 | | 1.0717 | 0.9331 | 3.8581 | 0.25919 | 8.506 | 117.57 | 2.8768 | 0.34761 | 6.342 | 0.15767 |
| Pd | 2 | 107.0 | 0.5542 | 1.8045 | 1.9951 | 0.5012 | 4.3984 | 227.30 | 1.4876 | 0.6722 | 3.2796 | 0.30491 |
| Pt | 4 | 194.9 | 0.5047 | 1.9813 | 1.8170 | 0.5504 | 4.0058 | 249.64 | 1.3548 | 0.7381 | 2.9869 | 0.33479 |
| Rh | 2 | 103.0 | 0.5335 | 1.8745 | 1.9205 | 0.5207 | 4.2339 | 236.19 | 1.4320 | 0.6983 | 3.1570 | 0.31675 |
| S | 1 | 32.07 | 0.33220 | 3.0102 | 1.1959 | 0.8362 | 2.6366 | 379.28 | 0.8917 | 1.1214 | 1.9659 | 0.5087 |
| " | 2 | | 0.16610 | 6.021 | 0.5980 | 1.6724 | 1.3183 | 758.6 | 0.44587 | 2.2428 | 0.9830 | 1.0173 |
| Sb | 1 | 120.4 | 1.2472 | 0.8018 | 4.4898 | 0.22273 | 9.898 | 101.03 | 3.3477 | 0.29870 | 7.381 | 0.13549 |
| " | 3 | | 0.41572 | 2.4054 | 1.4966 | 0.6682 | 3.2994 | 303.08 | 1.1159 | 0.8961 | 2.4602 | 0.40647 |
| Se | 2 | 79.2 | 0.41020 | 2.4378 | 1.4767 | 0.6772 | 3.2550 | 307.16 | 1.1011 | 0.9082 | 2.4275 | 0.41194 |
| Si | 4 | 28.4 | 0.07355 | 13.597 | 0.26476 | 3.7769 | 0.5837 | 1713.2 | 0.19742 | 5.065 | 0.43524 | 2.2976 |
| Sn | 2 | 119.0 | 0.6163 | 1.6225 | 2.2188 | 0.45069 | 4.8916 | 204.43 | 1.6545 | 0.6044 | 3.6474 | 0.27417 |
| " | 4 | | 0.30817 | 3.2450 | 1.1094 | 0.9014 | 2.4458 | 408.86 | 0.8272 | 1.2089 | 1.8237 | 0.5483 |
| Sr | 2 | 87.60 | 0.45371 | 2.2041 | 1.6333 | 0.6122 | 3.6000 | 277.71 | 1.2179 | 0.8211 | 2.6850 | 0.37244 |
| Te | 2 | 127.5 | 0.6604 | 1.5143 | 2.3773 | 0.42065 | 5.241 | 190.80 | 1.7726 | 0.5641 | 3.9080 | 0.25589 |
| Ti | 4 | 48.15 | 0.12469 | 8.020 | 0.44889 | 2.2277 | 0.9896 | 1010.5 | 0.33471 | 2.9876 | 0.7379 | 1.3552 |
| U | 4 | 239.6 | 0.6205 | 1.6117 | 2.2337 | 0.44768 | 4.9245 | 203.07 | 1.6656 | 0.6004 | 3.6720 | 0.27233 |
| V | 1 | 51.4 | 0.5324 | 1.8782 | 1.9167 | 0.5217 | 4.2258 | 236.64 | 1.4292 | 0.6997 | 3.1508 | 0.31737 |
| " | 2 | | 0.26622 | 3.7564 | 0.9584 | 1.0434 | 2.1129 | 473.29 | 0.7146 | 1.3994 | 1.5754 | 0.6347 |
| W | 2 | 184. | 0.9530 | 1.0493 | 3.4308 | 0.29148 | 7.564 | 132.21 | 2.5581 | 0.39091 | 5.640 | 0.17731 |
| Zn | 2 | 65.4 | 0.33873 | 2.9522 | 1.2194 | 0.8201 | 2.6883 | 371.98 | 0.9093 | 1.0998 | 2.0046 | 0.49886 |
| Zr | 4 | 90.4 | 0.23410 | 4.2716 | 0.8428 | 1.1866 | 1.8580 | 538.2 | 0.6284 | 1.5913 | 1.3854 | 0.7218 |
| | a | | n | n | n | n | n | n | n | n | n | n |
| | b | | a / b^n | b / a^n | a / b^n | b / a^n | a / b^n | b / a^n | a / b^n | b / a^n | a / b^n | b / a^n |
| | x | y | y / 0.010359^x | x / 96.54^y | y / 0.037291^x | x / 26.816^y | y / 0.08221^x | x / 12.164^y | y / 0.027806^x | x / 35.964^y | y / 0.06130^x | x / 16.313^y |

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(For the atomic weights of the other elements and the full names, see table of valencies below.)

The zinc is dissolved as sulphate, and always has a valency of II. From the table under Zn II, the pounds per horse-power hour for 1 volt (column 12) is 2.00, which, divided by 17 volts, gives 1.18 pounds per horse power hour, and this, multiplied by 10, gives 11.8 pounds. For the theoretical amount of energy, use the theoretical instead of the available voltage.

In the same way the amount of any element set free or dissolved by a given current or amount of energy, or the current or energy required for or given out by the setting free or dissolving of a given amount of any element, may be readily calculated directly from the figures in the table. When calculations involving the energy are made for both of the two electrodes, it must not be forgotten that the voltage measured at the terminals of the cell applies to the sum of both reactions taken together, and not to each one separately. This same voltage is used to calculate the total energy, irrespective of whether the calculation is based on the reaction at the anode or the cathode, and the energies must therefore not be added together when both are involved, as the same energy performs both operations. When the local energy at each electrode is calculated separately, as, for instance, from the thermochemical data, the two energies must, of course, be added to give the total; care must then be taken to add them algebraically, as they may have different signs. In the Daniell cell, for instance, energy is given out at the zinc electrode, but is absorbed at the copper, and the total is therefore the difference.

*Simple Case of Change of Valency.*—In many cases the element is neither set free nor dissolved; it simply changes its valency from one value to another. Such, for instance, is the case in the action of many of the so-called depolarizers, like the peroxide of manganese of the Leclanche cell, the peroxide of lead in the lead accumulator, the chromic acid or nitric acid in the Grove or the Bunsen cells. In such cases, find the valencies before and after the reaction, and the difference will give the change of valency which is to be used in obtaining the equivalents from the table. (The sign of this difference indicates the direction of the current, and is therefore not involved in the numerical values.)

*Example.*—How much manganese is involved in a discharge of 100 ampere hours from a Leclanche cell? In this case $2MnO_2$ changes into $Mn_2O_3$. The valency in the first is IV and in the second III, hence the change is I. The table gives 2.05 grams per ampère hour for Mn, with a change of valency of 1, hence for 100 ampère hours the amount of the element manganese involved is 205 grams. The amount of the peroxide corresponding to this is then found, as usual, by the well known chemical calculation: thus the molecular weight of the peroxide $MnO_2$ is $55 + (2 \times 16) = 87$, and that of the manganese is 55, hence $205 \times (87 \div 55) = 324$ grams $MnO_2$.

Those who do not wish to use this simple method, based on changes of valencies, may obtain the same result by the more lengthy and indirect chemical calculation. In such a case

write out the complete chemical equation, involving the zinc, the manganese and the ammonium chloride. Then calculate electrochemically the amount of zinc involved, as described above, and from this determine by purely chemical calculations the amount of the manganese or peroxide which corresponds to that amount of zinc. This will be illustrated in another example.

*Example Illustrating that the Subscripts May be Ignored.*—How much oxygen will be set free per ampère hour in electrolyzing sulphuric acid, $H_2SO_4$? The change of valency of oxygen is its full valency II, as it is set free; the result is therefore taken directly from the table, namely, 0.30 gram. It will be seen that this does not involve the subscript 4. It will be the same for $H_2O$ where the subscript is 1. The amount set free per ampere hour is a fixed and definite quantity, and is entirely independent of any arbitrary chemical formulas, provided only that the valency be known; and in the case of oxygen it is always II.

Similarly, in the case of cuprous chloride, CuCl, the amount of chlorine set free per ampère hour is the same as in cupric chloride, $CuCl_2$, namely, 1.32 gram per ampère hour, although the subscript is twice as great in the latter case. But the amount of copper deposited per ampère hour is twice as great from the former than from the latter, because the valency is half as great.

*Example Illustrating that Coefficients and Intermediate Reactions Can Be Ignored.*—How much nitric acid will be required in a Bunsen cell for 100 ampère hours, assuming that the nitric acid ($HNO_3$) is all reduced to nitric oxide (NO)? The chemical equation of the complete reaction is

$$3Zn + 3H_2SO_4 + 2HNO_3 = 3ZnSO_4 + 2NO + 4H_2O.$$

It will be noticed that to satisfy this equation there must be three molecules of zinc and only two of nitric acid, and it is very important to include those coefficients in making the purely chemical calculation. In the direct electrochemical calculation, however, these coefficients may be ignored entirely, and, in fact, need not be known at all, as the amount of any element corresponding to an ampère hour is a fixed and definite quantity as given in the table, and is independent of any equations or coefficients like these, the only factor that needs to be known being the change of valency.

Furthermore, in the reaction the zinc is dissolved in sulphuric acid, and the corresponding hydrogen reduces the nitric acid. It thus involves the intermediate reaction of the sulphuric acid. But in the direct electrochemical calculation of the nitric acid this intermediate reaction may also be completely ignored, as the amount of nitric acid reduced per ampere hour is, as said above, a fixed and definite quantity, which is entirely independent of any intermediate reactions, provided only that the change of valency is known.

The amount of nitric acid can therefore be calculated independently of either the coefficients or the consideration of any intermediate reactions that may be involved in the complete chemical equation. It is necessary only to know what it is changed into, so as to be able to find the change of valency. In the nitric acid the valency of the nitrogen is V, and in the nitric oxide it is II; hence the change in III, and, from the table, the amount of nitrogen for this change of valency is 0.1745 grams per ampère hour—that is, 17.45 grams for the 100 ampere hours. From this the amount of the acid is then readily calculated by the usual chemical method, as follows: The atomic weight of N is 14, and of nitric acid $1 + 14 + (16 \times 3) = 63$, therefore $17.5 \times (63 \div 14) = 78.5$ grams of nitric acid.

As stated in the previous examples, this same result may also be determined indirectly by starting with the amount of zinc corresponding to the 100 ampère hours, and then, by means of the above chemical equation, calculating the corresponding amount of nitric acid by plain chemical calculations. The change of valency of the nitrogen need not then be known, but the coefficients and the intermediate reactions must be known.

The amount of zinc per ampère hour, from the table, is 1.22 grams (the valency of zinc being always II), or 122 grams for 100 ampère hours. From the equation, every three atoms of zinc require two molecules of nitric acid; the atomic weight of zinc is 65.4, and the molecular weight of nitric acid is 63. Hence the 122 grams of zinc must be multiplied by $2 \times 63$ and divided by $3 \times 65.4$, which gives 78.4 grams of nitric acid, as before, neglecting the slight inaccuracies due to the abbreviated numbers.

*Example Involving a Change of Sign of the Valency.*—How much sulphur is involved per ampère hour in the oxidation of sulphuretted hydrogen, $H_2S$, into sulphuric acid, $H_2SO_4$? The equation is

$$H_2S + 4H_2O = 4H_2 + H_2SO_4.$$

In all the previous examples illustrating the more usual cases, the valencies of the element had the same sign before and after electrolysis, and their signs need therefore not be considered. In some cases, however, like in the present one, the sign of the valency changes, and therefore becomes very important. In every compound the bonds representing the valency must always add to zero. Those of hydrogen are always +, and of oxygen always —. In $H_2S$, therefore, the S must have two negative bonds (valency—II) to neutralize the two positive bonds of $H_2$; but in $H_2SO_4$ the S has six positive bonds (valency + VI), hence the change of valency is the *algebraic* difference, namely, 8 (the sign of which is of no importance here). The table does not contain this valency, but the result is easily obtained by dividing that for a valency of 1, namely, 1.20 by 8, as the amount per ampère hour decreases in proportion as the valency increases. This gives $1.20 \div 8 = 0.15$ gram of S per ampère hour. A change of sign of the valency from — to + implies oxidation (or perduction), and from + to —, reduction.

As in the previous example, the same result may also be obtained indirectly by starting with the amount of hydrogen liberated, and then calculating by purely chemical methods how much sulphur is involved in that equation. The change of valency or the change of sign need not then be known. From the table, 1 ampère hour sets free 0.0376 gram of hydrogen. From the last half of the above equation, every eight atoms of hydrogen set free correspond to one of sulphur in the $H_2SO_4$ formed. The atomic weight of sulphur is 32, hence $0.0376 \times (32 \div 8) = 0.15$ gram, the same as before.

In the reduction of nitric acid to ammonia in the presence of sulphuric acid, there is also a change of sign in the valency, but in this case from + to —, as it is a reduction. The equation is

$$2(HNO_3) + H_2SO_4 + 2H_2O = (NH_4)_2SO_4 + 4O_2.$$

In the nitric acid the valency of the N is + V, and in the ammonium sulphate is —III; hence the change of valency is 8. Or the calculation may be made indirectly by starting with the amount of oxygen set free, and then calculating by purely chemical methods the corresponding amount of nitrogen or nitric acid involved.

*Example Illustrating a Partial Change of Valency.*—How much nitric acid is required per ampère hour when used as a depolarizer in the Bunsen cell, assuming the nitric acid to be changed into ammonium nitrate? The complete reaction is

$$4Zn + 4H_2SO_4 + 2HNO_3 = 4ZnSO_4 + 3H_2O + NH_4NO_3.$$

The nitrogen in the nitric acid has a valency of +V, and in the $NH_4$ of the ammonium nitrate, —III; hence the change of valency is 8. Part of the nitrogen, however, does not change its valency, but remains as $NO_3$, and is therefore not involved in the electrochemical equivalent, the nitric acid thus performing a double duty. The equation shows that half of the N is involved in the change to $NH_4$, and the other half remains as $NO_3$. The former is calculated electrochemically, as above described, and the amount found must then be doubled in order to get the total.

The same result may be obtained indirectly by starting with the amount of zinc involved per ampère hour, and then calcu-

## LIST OF THE ELEMENTS WITH THEIR SYMBOLS AND PRACTICAL VALENCIES

*(By the word "salts" is meant oxides, sulphides, sulphates, chlorides, chlorates, etc.)*

| Name | Symbol | Atomic Weight | Valencies |
|---|---|---|---|
| Aluminium | Al | 27.1 | Salts +III; aluminates +III. |
| Antimony | Sb | 120.4 | Antimonous salts +III; antimonic salts +V; antimonites +III; antimonates +V; antimonides −III, sometimes −I and −II. |
| Arsenic | As | 75.0 | Arsenious salts +III; arsenic salts +V; arsenites +III; arsenates +V; arsenides −III, sometimes −I and −II. |
| Barium | Ba | 137.40 | Salts +II. |
| Beryllium | Be | 9.1 | Salts +II. (Same element as glucinum.) |
| Bismuth | Bi | 208.1 | Bismuthous salts +III; bismuthic salts and bismuthates +V. |
| Boron | B | 11.0 | Salts +III; borates +III. |
| Bromine | Br | 79.95 | Bromides −I; hypobromites +I; bromates +V. |
| Cadmium | Cd | 112.4 | Salts +II. |
| Cæsium | Cs | 132.9 | Salts +I. |
| Calcium | Ca | 40.1 | Salts +II. |
| Carbon | C | 12.0 | Carbonates +IV; salts usually +IV; in CO +II; hydrocarbons, free valencies −I to −IV. |
| Cerium | Ce | 139.0 | Cerous salts +III; ceric salts +IV. |
| Chlorine | Cl | 35.45 | Chlorides −I; hypochlorites +I; chlorites −III; chlorates +V; perchlorates +VII; monoxide +I; dioxide or peroxide +IV. |
| Chromium | Cr | 52.1 | Chromous salts +II; chromic salts +III; trioxide +VI; chromites +III; chromates or di-chromates +VI. |
| Cobalt | Co | 59.00 | Cobaltous salts +II; cobaltic salts +III. |
| Columbium | Cb | 93.7 | $CbO$ +II; $CbO_2$ +IV; columbic salts and columbates +V. (Same as niobium.) |
| Copper | Cu | 63.6 | Cuprous salts +I; cupric salts+II |
| Didymium | Di | | (See neodymium and praseodymium.) |
| Erbium | Er | 166.0 | Salts +III. |
| Fluorine | F | 19.05 | Fluorides −I; all compounds −I. |
| Gallium | Ga | 70.0 | Salts +III. |
| Germanium | Ge | 72.5 | Germanious salts +II; germanic salts +IV; germanites +II; germanates +IV. |
| Glucinum | Gl | 9.1 | Salts +II. (Same element as beryllium.) |
| Gold | Au | 197.2 | Aurous salts +I; auric salts +III, aurates +III |
| Hydrogen | H | 1.008 | Always +I. |
| Indium | In | 114.0 | Salts +III. |
| Iodine | I | 126.85 | Iodides −I; hypoiodites +I, iodates +V; periodates +VII, iodic oxide +V. |
| Iridium | Ir | 193.1 | Iridous salts +III, iridic salts +IV. |
| Iron | Fe | 55.9 | Ferrous salts +II; ferric salts +III; ferrates +VI. |
| Lanthanum | La | 138.6 | Salts +III. |
| Lead | Pb | 206.92 | Usual salts or plumbic salts +II di-oxide or peroxide and plumbates +IV; sub-oxide +I. |
| Lithium | Li | 7.03 | Salts +I. |
| Magnesium | Mg | 24.3 | Salts +II. |
| Manganese | Mn | 55.0 | Manganous salts +II; manganic salts +III; di-oxide or peroxide +IV; manganates +VI; permanganates +VII. |
| Mercury | Hg | 200.0 | Mercurous salts +I; mercuric salts +II. |
| Molybdenum | Mo | 96.0 | Molybdous salts +II; molybdic salts +III; di-oxide +IV; tri-oxide and molybdates +VI. |
| Neodymium | Nd | 143.6 | Salts +III. |
| Nickel | Ni | 58.70 | Nickelous salts +II; nickelic salts +III. |
| Niobium | Cb | 93.7 | (See columbium.) |
| Nitrogen | N | 14.04 | Ammonia and ammonium salts ($NH_4$ salts) −III; most organic nitrogen compounds −III; nitrous oxide +I; nitric oxide +II; sesqui-oxide and nitrites +III; di-oxide (peroxide) +IV; nitric anhydride and nitrates +V. (In ammonium nitrite and nitrate the N in the $NH_4$ radical is −III and in the acid radical +III or +V.) |
| Osmium | Os | 191.0 | Osmous salts +II; osmic salts +IV; sesqui-oxide +III; tri-oxide and osmates +VI; per-oxide and perosmates +VIII. |
| Oxygen | O | 16.000 | Oxides, salts, etc. −II. |
| Palladium | Pd | 107.0 | Palladous salts +II; palladic salts +IV. |
| Phosphorus | P | 31.0 | Phosphorous salts and phosphites +III; phosphoric salts and phosphates +V; phosphides −III; hypophosphites +I; hypophosphates +IV. |
| Platinum | Pt | 194.9 | Platinous salts and platinites +II; platinic salts and platinates +IV. |
| Potassium | K | 39.11 | Salts +I. |
| Praseodymium | Pr | 140.5 | Salts +III. |
| Rhodium | Rh | 103.0 | Rhodous salts +II; rhodic salts +III; di-oxide +IV. |
| Rubidium | Rb | 85.4 | Salts +I. |
| Ruthenium | Ru | 101.7 | Ruthenous salts +II; ruthenic salts +III; ruthenic anhydride and ruthenates +IV; per-ruthenic anhydride +VIII |
| Samarium | Sm | 150.3 | Salts +III. |
| Scandium | Sc | 44.1 | Salts +III. |
| Selenium | Se | 79.2 | Selenites +IV; selenates +VI; selenides −II. |
| Silicon | Si | 28.4 | Silicides −IV; salts, oxide and silicates +IV. |
| Silver | Ag | 107.93 | Salts +I. |
| Sodium | Na | 23.05 | Salts +I. |
| Strontium | Sr | 87.60 | Salts +II. |
| Sulphur | S | 32.07 | Sulphides −II; di-sulphides −I; $SO_2$ and sulphites +IV; $SO_3$ and sulphates +VI; hyposulphites (thio-sulphates) +II; $S_2O_5$ +III; $S_2O_7$ and per-sulphates +VII. |
| Tantalum | Ta | 182.8 | Salts and tantalates +V. |
| Tellurium | Te | 127.5 | Tellurides −II; di-tellurides −I; tellurous salts +II; telluric salts and tellurites +IV; $TeO_3$ and tellurates +VI. |
| Terbium | Tr | 160. | Salts +III. |
| Thallium | Tl | 204.15 | Thallous salts +I; thallic salts +III |
| Thorium | Th | 232.6 | Salts +IV. |
| Tin | Sn | 119.0 | Stannous salts and stannites +II; stannic salts and stannates +IV. |
| Titanium | Ti | 48.15 | Titanous salts and titanites +III; titanic salts and titanates +IV. |
| Tungsten | W | 184 | WO +II; $WO_3$ and $WCl_6$ +IV; tungstic oxide and tungstates +VI. |
| Uranium | U | 239.6 | Uranous salts +IV; urane salts and uranates +VI. |
| Vanadium | V | 51.4 | Vanadates +V; vanadous salts +III; VO +II; $VO_2$ +IV. |
| Ytterbium | Yb | 173.2 | Salts +III. |
| Yttrium | Y | 89.6 | Salts +III. |
| Zinc | Zn | 65.4 | Salts +II. |
| Zirconium | Zr | 90.4 | Salts and zirconates +IV. |

lating the corresponding amount of nitric acid by purely chemical methods, in compliance with the above equation. In such rare and somewhat complicated cases as this one, this indirect method will no doubt be the safer one to use by those not accustomed to the conception of negative valency or changes of valency.

*Example Illustrating the Exhaustion of the Electrolyte at Both Electrodes.*—How many ampere hours will it take to

extract the lead from a solution of nitrate of lead, $Pb(NO_3)_2$, containing 100 grams of lead, when electrolyzed between platinum electrodes? In this case the solution will be reduced at the cathode, where metallic lead will be deposited, while at the anode it will be oxidized, depositing the peroxide $PbO_2$, thus exhausting the solution of its lead at both electrodes. Nitric acid will be formed, and it is here assumed that it will not redissolve the lead by local action.

The equation is

$$2Pb(NO_3)_2 + 2H_2O = Pb + 4HNO_3 + PbO_2.$$

From this it is seen that an equal quantity of Pb goes out at each electrode simultaneously, hence 50 grams of lead will be deposited on each electrode. From the table, 1 gram will require 0.26 ampère hours, the valency of the lead on the cathode being II; hence $50 \times 0.26 = 13.0$ ampère hours will be required. At the anode, the valency of the lead has changed from II to IV, the change of valency being therefore II, which is the same as at the cathode; hence the amount of lead must be the same at both electrodes.

As in the previous examples, this calculation may be made without a knowledge of the change of valency by calculating the amount of metallic lead deposited on the cathode, and then, by a purely chemical calculation, finding the amount at the anode from the equation. In this case the equation shows at once that the amount of Pb on each electrode is the same.

*Example Illustrating a Deposition on One Electrode and a Change of the Solution at the Oother.*—How much cuprous chloride will be acted upon per ampère hour when electrolyzed between platinum electrodes? At the cathode copper will be deposited, while at the anode the chlorine will "oxidize" (or perduce) the cuprous chloride (CuCl) to cupric chloride ($CuCl_2$); there will therefore be no deposit or gas formed at the anode.

The equation is

$$2CuCl = Cu + CuCl_2.$$

The change of valency of the copper is I, not II, as is more usual; hence the number of grams per ampère hour is found directly from the table under a valency of I. The amount of the cuprous chloride corresponding to this is then calculated chemically, in the usual way, from the formula CuCl. This, however, will give only that reduced at the cathode. At the anode cuprous chloride is chloridized to the cupric, and, as this is, of course, not the same as was reduced at the cathode, it must be added to the other in order to give the total required for that same ampère hour. At the anode, the valency of the copper has changed from I to II, making a change of I, and the amount will therefore be the same as at the cathode; hence the total amount of CuCl will be double the amount corresponding to the copper set free, a fact which is also clearly seen from the coefficient 2 in the equation.

The calculation can also be made chemically from the equation, after having first calculated electrochemically the amount of copper set free at the cathode.

*Example Illustrating the Reduction of One Solution and the Oxidation of Another.*—If the cathode is in the copper sulphate and the platinum anode in ferrous sulphate, copper will be deposited on the cathode and the ferrous sulphate will be oxidized into the ferric sulphate. The formula is

$$CuSO_4 + 2FeSO_4 = Cu + Fe_2(SO_4)_3.$$

The copper has changed its valency from II to O, and the iron from II to III, from which all the quantities can be determined by the use of the table. Or from the Cu set free the other quantities can be calculated from the equation by purely chemical calculations.

*Example Illustrating a Case in Which Nothing is Set Free or Dissolved at Either Electrode.*—If the platinum cathode is in a solution of ferric sulphate and the platinum anode in ferrous sulphate, then at the cathode the ferric sulphate will be reduced to ferrous, and at the anode the ferrous will be oxidized (or perduced) to ferric; no gas or metal will be set free or dissolved at either electrode. Fe ions pass from the solution around the anode to that around the cathode, and $SO_4$ ions pass in the reverse direction. The reaction is as follows:

$Fe_2(SO_4)_3$ (at cathode) + $2FeSO_4$ (at anode) = $2FeSO_4$ (at cathode) + $Fe_2(SO_4)_3$ (at anode).

The valency of the Fe in the ferric state is III and in the ferrous II, hence there is a change of I, from which the electrochemical equivalent is found, in the table, to be 2.08 grams per ampere hour. This means that 2.08 grams of iron in the ferrous state will be oxidized at the anode to the ferric state by one ampère hour, and that 2.08 grams of iron in the ferric state will be reduced to the ferrous state at the cathode.

It is here assumed, of course, that there is always enough of the salt present around each electrode to enable this reaction to take place, otherwise some other reactions will begin, such as the deposition of iron on the cathode (change of valency II) or the evolution of oxygen at the anode. Too strong a current will also be apt to cause other simultaneous reactions. Attention is also called to the fact that the relative velocities of migration of the ions through the diaphragm may affect the relative amounts of the salts found on the two sides of the diaphragm after the passage of the currents, as Faraday's law has nothing to do with that; but the amount of iron oxidized or reduced per ampère hour is, according to Faraday's law, a fixed and definite quantity, found from the table, irrespective of which side of the diaphragm the salt will be found on after the passage of the current.

This is a case in which the method of calculation, based on the change of valency, is far simpler than the older one, based on the chemical equation, for the reason that there is nothing tangible set free or dissolved which could be used as a basis of the calculation, as there was in all the other examples. One cannot use the iron in this case as the basis, because it has two different valencies at the two electrodes, and it would give entirely wrong results to use either of these valencies. There may be various ways of calculating the result without involving the conception of the change of valency, but the simplest one of these seems to be to start with the $SO_4$ ions as a basis and then determine from this, by a chemical calculation, the amount of iron involved in the reaction. This $SO_4$ may be assumed, for the purpose of calculation, to pass from the ferric sulphate to the ferrous sulphate, thereby reducing the former and oxidizing (or perducing) the latter. This compound ion can safely be assumed as the basis of this calculation, because it always has, in sulphates, the same valency, namely, II, and the amount involved per ampère hour, therefore, is a constant in all sulphates. This constant amount may be found from any convenient sulphate, such as sulphuric acid, for instance, $H_2SO_4$, and it will be the same for both the ferric as the ferrous sulphate.

From the table, the amount of hydrogen per ampère hour is 0.0376 grams, and, as the atomic weight of $SO_4$ is 96, and that of $H_2$ is 2.02, the electrochemical equivalent of $SO_4$ is $0.0376 \times (96 \div 2.02) = 1.79$ grams per ampère hour. At the anode, one $SO_4$ combines with two $FeSO_4$ to form one $Fe_2(SO_4)_3$. Therefore, as 2Fe (atomic weight $2 \times 55.9 = 111.8$) corresponds to the addition of 96 of $SO_4$, it follows that $1.79 \times (111.8 \div 96) = 2.08$ grams of iron are involved per ampère hour at the anode, which is the same as was found above in the first and much simpler calculation based on the change of valency of the iron. A similar calculation based on what takes place at the cathode will give precisely the same result, as here, again, 2Fe correspond to one $SO_4$, the only difference being that it is a loss at the cathode, while at the anode it is a gain.

*Similar Example, Involving, in Addition, a Chemical Reaction.*—The cathode is in a solution of chromic acid with sulphuric acid; the platinum anode is in a solution of ferrous sulphate. Nothing is set free or enters at either electrode. The complete equation is

$$2H_2CrO_4 + 6H_2SO_4 + 6FeSO_4 = Cr_2(SO_4)_3 + 8H_2O + 3\,Fe_2(SO_4)_3.$$

The chromic acid will be reduced, which would form a precipitate; but this is soluble in the $H_2SO_4$, forming chromium sulphate. The Cr has changed its valency from VI to III, hence the change of valency is III. At the anode, the ferrous sulphate has changed to the ferric, the iron having changed its valency from II to III. The sulphuric acid has a double function; half of it is electrolyzed, the $SO_4$ going to make the ferric sulphate and the $H_2$ forming water, while the other half acts purely chemically by dissolving the reduced chromic acid, forming chromium sulphate and water. The latter half of the sulphuric acid would therefore not be included in the electrochemical equivalent, but must be added to that found from the table. In such cases it is safest to use the chromium or the iron in the electrochemical calculations, and then calculate the required amount of sulphuric acid from the above chemical equation. It may be of interest to note here that this reaction forms an odd kind of accumulator, in which only the liquids enter into the reaction, the plates themselves remaining completely unchanged.

Here, again, the more complicated method of calculation, based on the chemical equation, might be used, as was shown in the previous problem, taking one $SO_4$ as a basis and calculating the other quantities from it.

HOW TO DETERMINE THE VALENCY.

In order to use this simpler method of change of valency in calculations involving the electrochemical equivalent, it is very necessary, of course, to know what the valencies are. Those who cannot determine these changes in valencies with the assistance indicated below must use the older, indirect and generally more lengthy chemical calculation, after having determined electrochemically the amount of some one convenient quantity in the equation.

It would be difficult, if at all possible, to give complete rules for determining the valencies, nor is it the object to do so here. The simplest way is to get them from the table which follows, and which was kindly prepared for this article by Prof. J. W. Richards. It gives what he calls the "practical valencies;" that is, the actual valency, irrespective of any interpretation involving a structural formula. He also gives their signs. There are others which occur more rarely, and still others about which there is some doubt. In such cases the safest method of calculation is the older one, based on the chemical equation, as was explained in connection with each example.

This table also gives the full names of all the elements in alphabetical order, while the other contains only the more important elements classified in the alphabetical order of their symbols. It also contains the atomic weights (based on O = 16) of all the elements, thus enabling one to calculate (by means of the formulas in the last line of the first table) any of the electrochemical equivalents or their derivatives of the elements not included in the first table.

The following few general rules concerning valencies may often be found useful: The valency expresses the number of bonds uniting an element with others in a compound. These bonds (as far as electrolysis is concerned) are negative and positive. For each negative bond of an element in a compound, there must of necessity be a corresponding positive bond of some other element. Each of these negative bonds corresponds to a charge of —96,540 coulombs (or 26.82 ampère hours) of electricity per uni-valent gram ion, and each positive bond to +96,540 coulombs. A change of valency implies a disappearance or appearance of positive and negative bonds, and hence a passage of electricity corresponding in amount to these charges set free or taken up.

An atom of oxygen is assumed to always have two negative bonds; hydrogen always one positive; chlorine (in chlorides) always one negative; $SO_4$ (in sulphates), always two negative; $NO_3$, always one negative; $ClO_3$, always one negative. In metallic solutions, where the metal is the base, its bonds are positive, while those of the radical are negative. Elements in their uncombined form (as deposited metals or free gases) are assumed to have no bonds. These few rules, together with the rule that all the positive and negative bonds must always add to zero, will enable one to find the valencies in most of the usual electrolytes.

This conception of negative valencies, which makes it possible to apply these rules concerning the change of valency to all cases, appears to have originated with Prof. Otis C. Johnson. He did not, however, apply it to electrochemical calculations. The conception of the change of valency as a basis of electrochemical calculations is the same thing, in different words, as the conception of charges received and given off by the ions at the electrodes, which is so frequently used in connection with the dissociation theory. But the use of the table as above described avoids the lengthy calculation involving the ionic charge 96,540, as this constant is already included in the figures given in the table.

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## ALUMINIUM AS A REDUCING AGENT IN METALLURGY.

By George P. Scholl.

The fact that metallic aluminium, under proper conditions, reduces many of the other metals from their compounds has been known a long time ago. No less a personage than the illustrious Friedrich Woehler, the discoverer of aluminium, tried, in 1857, to produce chromium from its chloride by means of metallic aluminium, and succeeded in obtaining a chromium-aluminium alloy. Numerous attempts have since been made by various investigators—among them Michel, St. Claire-Deville, the brothers Tissier and last, not least, Messrs. Greene and Wahl in Philadelphia—to utilize this reducing property of aluminium for practical purposes. But the stumbling block in the path of these experimenters was the fact that the reduction only takes place at a high temperature, and when this temperature has been reached it proceeds with explosive violence. It was left to Dr. Hans Goldschmidt,

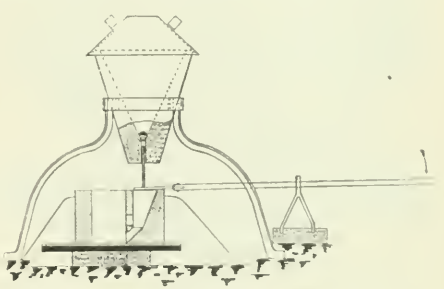


FIG. 1.—SECTIONAL VIEW OF CRUCIBLE ARRANGED FOR TAPPING.

Essen, Germany, to find out the means by which to temper the violence of the reaction and to evolve what is now known as the Goldschmidt process.

In the course of his researches, prompted by the firm of Friedrich Krupp, of Essen, and undertaken with a view to find a process for the manufacture of pure chromium and manganese, he discovered that, in order to have the reaction take place, it was only necessary to start it at one point of the mixture. As the reduction of metallic compounds by aluminium is an exothermic reaction, and takes place with a considerable evolution of heat, the heat liberated at that one point is sufficient to raise the adjacent portions of the mixture to the temperature of reaction, and so on, until the reaction has propagated itself throughout the entire mixture. This, then, was the keynote to a successful application of the aluminium reduction process in practice, but there remained a very serious

problem to be solved yet, namely, to find the best method to start the reaction. After many fruitless attempts, it was finally discovered that substances like the peroxides, chlorates, etc., which easily yield up their oxygen, could be successfully used for this purpose. It requires comparatively little heat to bring them to the point of reaction, and the heat given out thereby is sufficient to start the ignition of the mixture to be reduced. Barium peroxide has been found most satisfactory, and is most generally used.

As a typical example of the method of procedure, it will suffice to describe the reduction of metallic iron from its oxide by means of aluminium. The chemical equation, according to which the reaction takes place, is exceedingly simple, namely, $Fe_2O_3 + 2Al = Al_2O_3 + 2Fe$. The aluminium acts just like

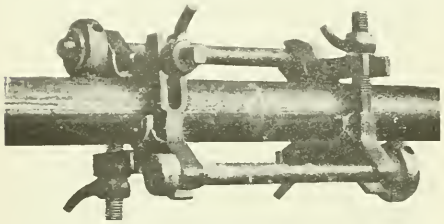


FIG. 2. PIPES CLAMPED TOGETHER BEFORE THE MOLD IS PUT AROUND.

the carbon in the ordinary reduction process, but while the products of combustion in the case of carbon (carbon monoxide and dioxide) are gaseous, the product of combustion in this case is a solid, which, however, becomes fluid through the heat of reaction. The oxide of iron is mixed with powdered aluminium in the right proportion, and introduced into a crucible lined with magnesia or with material obtained from a previous fusion. The mixture cannot be treated in an ordinary crucible, as the alumina, being of a strong basic character, would, at the high temperature developed in the process, immediately combine with the silica of the crucible and destroy it. Ordinarily the mixture would be very hard to ignite, as it can be thrown into an ordinary fire, and even upon molten cast iron, without burning. In order to set off the mixture, a

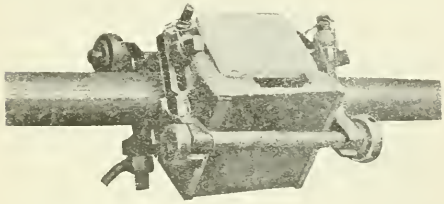


FIG. 3.—HORIZONTAL PIPES WITH MOLD, READY FOR POURING.

small quantity of ignition powder (barium peroxide and powdered aluminium) is put in a small heap on top of the mixture, and is ignited by means of a storm match or by touching it with a red-hot iron rod. The reaction propagates itself quickly through the whole mixture, with the result that in a few seconds the whole charge is a mass of white-hot fluid material. The contents of the crucible have separated into two layers, the molten metal, reduced by the aluminium, being at the bottom and the molten $Al_2O_3$, corundum, above it. That the heat developed during the operation is very great can be seen from the fact that the alumina, the melting point of which lies at about 1,900° C., is liquefied. The temperature of the molten mass in the interior of the crucible has been estimated at 3,000 C. (5,400° F.).

In order to understand the remarkable development of heat in this process, it has to be considered thermo-chemically and a comparison made between the energy density in the crucible and the energy density obtained in other sources of high temperature—for instance, the electric furnace. Starting from the reaction, $Fe_2O_3 + 2Al = Al_2O_3 + 2Fe$, there are required, theoretically, .484 kilograms aluminium for the production of 1 kilogram of metallic iron, furnishing .91 kilograms of alumina. Assuming the heat of combination of 1 kilogram Al to $Al_2O_3$ as 7,140 calories, as determined by Dr. Straus, of Friedrich Krupp, in Essen, there are set free in the above reaction $.484 \times 7{,}140 = 3{,}455.76$ calories. These calories have to furnish the heat necessary for the reduction of the iron, the heating of the iron to its melting point and the heating of the resulting alumina to its melting temperature.

Assuming the average heat necessary for the reduction of Fe from $Fe_2O_3$ as 1,768 calories, 1 kilogram of Fe will require 1,768 calories. If we take the melting point of wrought iron at 1,000° C., the average specific heat of wrought iron between 0 and 1,600° as .19 and the latent heat of fusion as 33 calories, the iron, in order to be melted, requires 337 calories. Finally, taking the melting point of alumina as 1,900° C., its specific heat as .2173 and its latent heat of fusion as 50 calories, we get 425.71 calories required for the melting of the alumina. The balance, therefore, neglecting the loss by radiation, is as follows:

| | | |
|---|---|---|
| Heat generated | | |
| By the reaction of .484 kg aluminium | | 3455.76 cal. |
| Heat required | | |
| For the reduction of 1 kg. $Fe_2O_3$ | 1768 cal. | |
| For the fusion of the metallic iron | 337 " | |
| For the fusion of the alumina | 425.71 " | 2530.71 cal |
| | | 925.05 cal |

There is, therefore, a surplus of heat of 925.05 calories, and, as 1 kilogram of the mixture of oxide of iron and aluminium

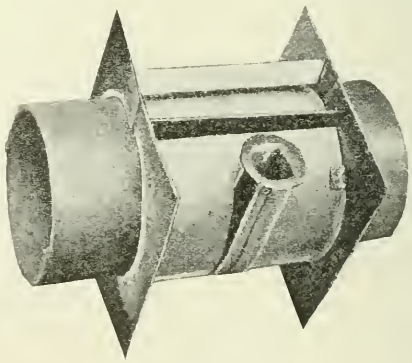


FIG. 4.—MOLD FOR PIPE OVER 5 IN. WIDE.

gives practically ½ kilogram of iron, there are about 450 calories of heat furnished for each kilogram of the mixture. In order to understand why such a relatively small amount of heat could cause the raising of the mixture to such a high temperature as 3,000° C., we must recall the fact that the reaction takes place with great velocity, and that, furthermore, the product is not a gas, as in the case of carbon, for the gasification of which a large amount of the energy has to be expended, but solid, and that the whole energy of the reaction is preserved, as it were, in the crucible.

The average time of reaction of 1 kilogram of the mixture is about one or two seconds, and with large quantities this time is still considerably reduced. Supposing that only 300 calories in one second are developed by the reaction of 10 kilograms of the mixture, the work done would equal $300 \times 425 = 127{,}500$ meter kilograms, or 1,700 horse-power seconds, or 1,149.5 kilowatt seconds, nearly equaling the effect in one second of an arc lamp of 30,000 ampères at 40 volts.

The data given above are taken from a recent paper read by Dr. Goldschmidt before the Society of German Chemists (*Zeitsch. Anorg. Chemie*, 1902, p. 099), where he also gives a comparison between the energy density developed in his process and in the electric furnace, which is of considerable interest to electrochemists. The energy density is calculated in ergs per cubic centimeter. As calculated above, there are available 450 calories for each kilogram of the mixture, and when 10 kilograms react in fifteen seconds, and occupy a space of 3,500 c.c. after the reaction has taken place, there are in 1 c.c. 0.0857 calories = 36.42 mkg. As 1 mkg = 98,100,000 ergs, there are in one second in one c.c. 3,572,802,000 ergs. In an electric furnace like that of Stassano, where the heat is generated by a powerful arc, heating a space of about 1 cubic meter, with an expenditure of energy of 500 horse-power, the energy density is 500 horse-power = 37,500 mkg in 1,000,000 c.c. per second, consequently per second per c.c. 0.0375 mkg. = 3,678,750 ergs, or nearly as 1 to 1,000 as compared with the Goldschmidt crucible. The following table gives a comparison with the energy density of a 500 horse power calcium carbide furnace:

| Time of reaction | Amount of mixture | Volume of the Reaction product | Heat generated | | Energy | | Kind of material treated |
|---|---|---|---|---|---|---|---|
| | | | Total calories | Available calories | Total energy | Available energy | |
| 15 sec. | 10 kg. | 3.5 l. | 4500 cal. = 1890 mkg. | 4500 cal. = 1890 mkg. | 185.4 mkg. = 1818 ergs. | 185.4 mkg. = 1818 ergs. | Calcium carbide |
| 1 hr. | 500 kg. | 175 cbm. | 225000 cal. = 94500 mkg. | 225000 cal. = 94500 mkg. | 9270 mkg. = 90957 ergs. | 9270 mkg. = 90957 ergs. | Calcium carbide |
| 1 hr. | 500 kg. | 175 cbm. | 225000 cal. = 94500 mkg. | 225000 cal. = 94500 mkg. | 9270 mkg. = 90957 ergs. | 9270 mkg. = 90957 ergs. | Calcium carbide |

Of the many applications which the process finds, one of the most important is the production of pure chromium and manganese. Chromium, as is well known, is a most valuable constituent of steel, but until it was made possible to obtain it by the Goldschmidt process it had to be manufactured either in crucible furnaces or in the electric furnace by reducing chrome iron ore with carbon. This, of course, gave not a pure material, but a so-called ferro-chromium, containing about 63 per cent. of chromium and a large amount, up to 12 per cent. of carbon. When this material was introduced into steel, the carbon which it contained added itself to the percentage of carbon already present in the steel. It was therefore impossible to produce a chromium steel low in carbon and at the same time containing an appreciable amount of chromium. The pure metal is now produced by the Goldschmidt process in large and increasing quantities, and finds a number of applications in the manufacture of special steels, as well as in the manufacture of guns, shells and armor plate.

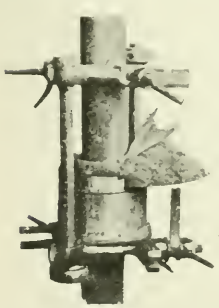


FIG. 5.—MOLD WITH LATERAL POURING FUNNEL FOR VERTICAL PIPES.

The reduction of chromium is very simple, taking place according to the equation $Cr_2O_3 + 2Al = Ae_2O_3 + 2Cr$. The mixture of finely-powdered aluminium and chromic oxide is made in the usual way, and the reaction started by igniting the charge with the ignition powder. The metal in a fused condition collects at the bottom of the crucible, with the corundum slag above it. The process is a strong rival of the electric furnace process for the production of ferro chromium, especially as the latter is not of such uniform composition as regards the carbon as is absolutely necessary where alloys of a definite composition have to be obtained. It is also probable that the process will cut short the efforts to produce pure metallic chromium by electrolysis.

Manganese is also produced of a high degree of purity, up to 99 per cent., the impurities being mostly iron and silicon. It is used to a large extent for copper-bronze and nickel castings. An alloy of 70 per cent. manganese and 30 per cent. chromium is used for the manufacture of special copper alloys, the so called copper manganine. Pure manganese is also used in the steel industry for the production of special steels high in manganese, containing up to 12 per cent. of that metal.

Ferro titanium is another product of the process. The mixture of aluminium with the titanium compound is inflamed by contact with molten cast iron, acting in this way different from the mixture of oxide of iron and aluminium, which is only ignited at the temperature of molten steel. This behavior is made use of for alloying titanium with cast iron by throwing the mixture right on the bath of molten metal. An alloy of ferro titanium is formed with the evolution of considerable heat, which combines directly with the cast iron. The mixture is added in quantities of ½ to 1 per cent., and, within these limits, has a very beneficial effect in making the cast iron finer grained, less brittle and more thinly fluid. In steel castings,

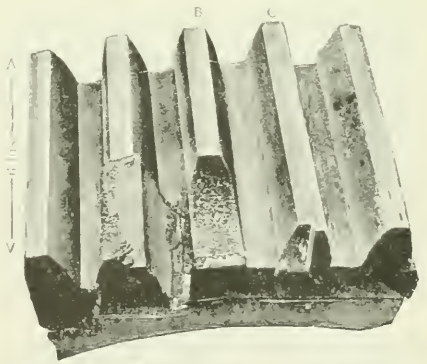



FIG. 6.—SECTION OF A WHEEL FOR REPAIRING.

considerably smaller additions of titanium are sufficient to produce solid castings. The cast iron on which the titanium mixture is thrown has to be sufficiently hot, otherwise the ignition will not take place and some of the metallic aluminium may alloy with the iron, producing unfavorable results.

One of the most interesting of the applications of the process, and probably the most widely used at the present time, is the employment of a mixture of oxide of iron and aluminium, in certain proportions, for welding and repairing purposes. This mixture is called by the inventor "Thermit." Two methods can be used for the welding, the first one depending merely on the utilization of the enormous heat which is developed during the reaction for the heating of the pieces to be welded, and in the second the welding is accomplished by means of the molten, white-hot iron produced. The first one of these methods is chosen where it is desired to weld pipes or pieces of iron together with their butt ends. The butts are fitted well together, and the ends to be welded are cleaned with a file or emery paper. They are then clamped firmly together, and a mold made from strong sheet iron is put around them. In pipes over 5 inches diameter, the pipe has to be completely surrounded by a mantle, with pouring funnel, and a large hole has to be provided for the exit of the air. Pipes can be welded in any position, only the mold has to be

changed to suit the purpose. Several arrangements are illustrated in the accompanying figures. The necessary amount of thermit is then brought to reaction in a crucible, and the contents of the crucible are poured into the mold. When the molten corundum, which flows out first, comes into contact with the cold pipe and the metal of the mold, a layer of chilled corundum forms on them, which cannot be melted any more by the following corundum or molten metal. If the latter would come into contact with the unprotected pipe, it would melt it through at once. The molten mass quickly brings the iron to the welding heat, and then the set screws, which hold the pieces of pipe, are drawn together and the pipes thus pressed closely against each other.

With vertical pipes, the mixture has to be quickly removed, because the ring of metal on the bottom of the mold might stick to them. With horizontal pipes, this is not necessary, and it is better to let the weld cool slowly. Square, round or shaped iron can be welded in the same way. Exact specifications have been prepared for welding pipes from ¾ inch up to 6½ inches diameter, giving amount of thermit necessary, diameter of the mold, etc.

It is important to note that this method of welding is also applicable for coils, which can be welded *in situ* after the parts have been previously bent to the desired form. The welding by this method is of such excellence that the welded part is stronger than the other parts of the pipe. One reason for this is the absolute exclusion of the air during the welding

FIG. 7—RAIL WELDING BY THE GOLDSMITH PROCESS.

process. The welding is, further, absolutely equal in all cases where the same quantity of thermit has been taken, and consequently exactly the same amount of heat has been generated.

The second method, in which the metallic iron produced in the reaction is utilized for uniting the objects to be welded, is carried out in a crucible, shown in cross section in the illustration. The conical crucible has a hole in the bottom, which, during the operation, is closed by a small iron disk, on which is placed a thin layer of fine sand. When the reaction is finished, the small iron disk is pushed up by means of a lever and the contents of the crucible run into the mold. If no layer of sand is put on the iron disk, it will melt through before all the thermite has entered into reaction. The molds have, of course, to be thoroughly dried. The iron produced in the reaction is a very pure wrought iron, specimens showing a composition of C = .10 per cent., Mn = .08 per cent., Si = .09 per cent., S = .03 per cent., P = .04 per cent., Cu = .09 per cent. and Al = .07 per cent. On account of its high temperature, of about 3,000° C., when poured on an object of iron, it softens its surface and welds itself firmly to the object. This method of welding has been used a great deal for welding tramway rails together, in order to avoid the various troubles arising from bad connections between the rails. The rails can be united either by butt-welding them or by simply casting a connection around their ends. The equipment necessary for welding rails is shown in an adjoining figure.

Another important feature of the process is the ease with which it can be applied to carrying out repairs in all kinds of castings. An example of this is shown in the illustration, where the teeth of a gear wheel have been repaired. The tooth on the left shows the repaired tooth before the surface is planed off; the one on the right is partly planed off, and the center tooth is left unrepaired, to show the appearance of the break. It is thus possible to save valuable castings which otherwise would have to go to the scrap heap. The process is also well adapted for the patching up of faulty castings, and, in fact, has such a wide applicability in many instances which are daily encountered in iron foundries and mills that any progressive manager ought to familiarize himself with it. Broken shafting can be welded and repaired in place, and it is stated that even ships' propeller shafts can be repaired at sea, as the apparatus for the purpose is very simple and no large quantities of molten material have to be transported. Instances like this might be multiplied, but they will readily suggest themselves to anyone familiar with foundry and mill work. The increasing application which the process has found in the leading iron and steel works abroad speaks volumes for its practical success.

Altogether, the process is a most interesting one to metallurgists, and has attracted considerable attention. It has not been a haphazard invention, but the result of a painstaking research by a man of broad scientific training, and the inventor has to be congratulated on his success in solving a problem which has baffled experimenters for a long time.

The writer wants to express his thanks to Mr. C. E. Schulz for valuable information on special points in connection with this subject.

## WHY THE E.M.F. OF THE DANIELL CELL CHANGES WITH THE DENSITY OF THE SOLUTIONS.

By Prof. Henry S. Carhart.

In my paper on "A Thermo-Electric Theory of Concentration Cells," read at the Niagara meeting of the American Electrochemical Society, I ventured to give a new explanation of the well-known dependence of the E.M.F. of the Daniell cell on the concentration of the two solutions. The explanation is based on the fact brought out in my paper that the thermo-electromotive force between a metal and a solution of one of its salts increases with the concentration of the solution. The relation between the two is shown in Fig. 4 of my paper, as published in Vol. II of the Transactions of the Society. The thermo-electromotive force is directed from the solution to the metal. Since this is in the opposite direction to the E.M.F. of the cell itself at the zinc electrode, an increase in the thermo-electromotive force at the zinc lowers the E.M.F. of the cell. At the copper electrode, on the other hand, an increase in the thermo-electromotive force increases the E.M.F. of the cell. Now when the concentration of the zinc sulphate solution is increased, the counter E.M.F. of thermal origin at the zinc electrode also increases, and, therefore, the E.M.F. of the cell decreases. Similarly an increase in concentration of the copper sulphate solution increases the thermal E.M.F. at the copper electrode, and this increase adds to the E.M.F. of the cell.

In the October number of this journal Prof. Jos. W. Richards has indirectly called in question my explanation of the phenomenon under discussion by offering another one, namely, the variation in the heat of formation of zinc and copper sulphates, in aqueous solution, with the concentration of the solutions formed. The heat of formation of both sulphates decreases as the concentration increases. The more dilute the solution, the greater the heat of formation. The same relation holds in the case of zinc chloride solution. This fact is brought out in the

classical researches of Jahn, which supported and confirmed the famous Gibbs-Helmholtz equation for the E.M.F. of a voltaic cell. If, therefore, the zinc is dissolved in a more concentrated solution, the formation heat of the zinc salt is less, and the E.M.F. of the cell is diminished. If, on the other hand, the copper is deposited from a more concentrated solution, in which the heat of formation of the copper salt is less, the value of the heat energy transformed in the cell is increased, and its E.M.F. is also increased.

The criticism of Professor Richards has led me to make a few measurements. The results are certainly interesting, and to my mind they are decisive as to the competency of the explanation which I gave in my Society paper. I say "competency," because I do not claim that this explanation excludes others when the subject is approached from a different point of view.

I set up a small Daniell cell of the two-legged variety, connected by small lateral tubes and a short piece of rubber tubing, the same as I have heretofore often used in my measurements of thermo-electromotive forces. In the rubber tube was a short piece of pipe stem to serve as a porous partition. The zinc side of the cell contained first a one-sixteenth normal zinc sulphate solution, and subsequently a normal solution. The E.M.F. was carefully measured in both cases by means of a Wolff's potentiometer or compensation apparatus, and the difference was 0.021 volt at 20° C. The value calculated from the difference in the two thermo-electromotive forces at the zinc surface alone would be somewhat higher. For the 1-16 normal solution the thermo-electromotive force per degree C. is 0.0007 volt; for the normal solution it is 0.0008 volt. The difference multiplied by the absolute temperature gives the calculated value of the variation of the E.M.F. when the one solution is substituted for the other in a Daniell cell. The product is 0.029 volt. The thermal electromotive forces are therefore ample to account for the observed variation in the E.M.F. of the cell. In this calculation I have not taken into account any small thermal E.M.F. at the junction of the two solutions.

The very interesting fact in this connection is that the change in E.M.F. of the Daniell cell when the one zinc sulphate solution is substituted for the other is the same as the E.M.F. of a concentration cell set up with zinc electrodes and the two solutions. A little consideration will serve to show that this should be the case. Suppose two similar Daniell cells set up with the same concentrated copper sulphate solution, one with the 1-16 normal zinc sulphate, and the other with the normal solution. Suppose, further, that the two are connected in opposition. The potential difference would then be the difference in E.M.F. of the two cells. This combination would be like a zinc concentration cell with the two halves connected by a tube containing copper sulphate separated from the zinc sulphate on the two sides by porous partitions. In confirmation of this view, I joined two such Daniell cells in opposition, and added in series with them a zinc sulphate concentration cell set up with the same solutions, 1-16 normal and normal. The concentration cell was turned so that its E.M.F. opposed that of the two Daniells. As anticipated the three cells balanced within 1/1000 volt. A separate measurement of the two Daniells in series and of the concentration cell gave the same result.

Hence, any competent explanation of a simple concentration cell is directly applicable to explain the variation in the E.M.F. of a Daniell cell with a change in concentration of the solutions.

Ideally a concentration cell is one containing no internal chemical energy to be transformed. Such is the case when the solutions are so dilute that they generate no heat when mixed. The heat of dilution is then negligible. The first term in the Gibbs-Helmholtz equation is then also negligible, and the second one, involving the absolute temperature and the temperature co-efficient is the sole expression of the E.M.F. But the temperature co-efficient is the sum of all the thermo-electromotive forces at the several junctions in the cell, all taken with their proper sign. All this rests on the surest experimental facts, and this constitutes the thermo-electric theory of a concentration cell. Such a cell converts heat into electrical energy. In the limit, when there is no internal chemical energy, all the heat is absorbed from the surroundings. On the more dilute side, where the current flows in the opposite direction to the thermo-electromotive force, the heat generated is the combined product of the absolute temperature, the temperature co-efficient or thermo electromotive force at that electrode, and the quantity of electricity passing. On the other side, where the current flows in the same direction as the thermo electromotive force, the heat absorbed is the same combined product; but the latter is larger than the former because the thermo electromotive force is greater. In the measurements which I have made it is enough greater to account for the whole E.M.F. of the cell. Hence the heat of solution must be negligible, or else the necessary heat absorbed comes in part from the dilution. This point is capable of experimental determination by one of the methods used by Jahn in his well known researches.

The explanation applicable to the concentration cell may be carried directly over to the Daniell cell and applied to explain the change of E.M.F. due to a change of concentration.

The foregoing measurements show that for the concentrations used the E.M.F. of the concentration cell is the same as that of the two Daniells in opposition. This result is not in agreement with the conclusion of Nernst that the E.M.F. of the concentration cell is to the difference of the two Daniells as the ionic velocity of the anion is to the sum of the ionic velocities of the anion and the cation. (See Jaeger's *Die Normalelemente*, p. 29).

## TWO GERMAN PLANTS FOR STERILIZING WATER BY OZONE.

The first two German plants in which electrically produced ozone is used as a sterilizing and oxidizing agent in connection with commercial water works, were opened last autumn in Schierstein, near Wiesbaden, and in Paderborn. That ozone is well adapted for water sterilization, being a powerful destroyer of organic matter, both vegetable and animal, is well known and requires no longer proof by practical experiments. But the all important question is whether the cost of this

FIG. 1—OZONIZER ROOM.

method is not prohibitive. This question, however, can be decided only by actual practice on a commercial scale, and for this reason all facts published on commercial plants must be of interest. A method used at two Dutch plants was described in ELECTROCHEMICAL INDUSTRY, September 1902, Vol. I, pages 31 and 32; in these plants the Vosmaer Lafaret system is used. The two German plants which will be described in the following, were installed by the Siemens & Halske Co. of Berlin.

The plant at Schierstein was installed to the order of the

municipal authorities of the city of Wiesbaden, and is designed to sterilize 250 cubic meters (66,000 gallons) of water per hour as a maximum, as stated in recent articles in *Schilling's Jour. f. Gasbel u. Wasserzers*, 1902, No. 40, and in *Zeit. f. Elektrochemie*, 1902, No. 43. But this maximum output is required only for occasions when exceptionally large amounts of water are needed, while in the average only one-half, *i. e.*, 125 cubic meters (33,000 gallons) are sterilized per hour. The other half of the plant serves in general as reserve; the plant is therefore divided into two independent halves, but the apparatus of one half may be worked in connection with the other half, for instance, each set of dynamos may be easily switched over from one-half to the other.

The dynamos installed give current for driving the pumps and also current for the transformers. The transformers are wound for 180 volts primary and 8,000 volts secondary, the secondary windings being connected to the ozonizing apparatus. The ozone produced is then driven by fans into the sterilizing towers, in which the ozone rises upwards and comes into contact with the water flowing down; the water is thus sterilized and flows off into a reservoir.

In the ozonizer room there are 48 ozonizers at both walls of the room, as shown in Fig. 1. As noticed before the whole

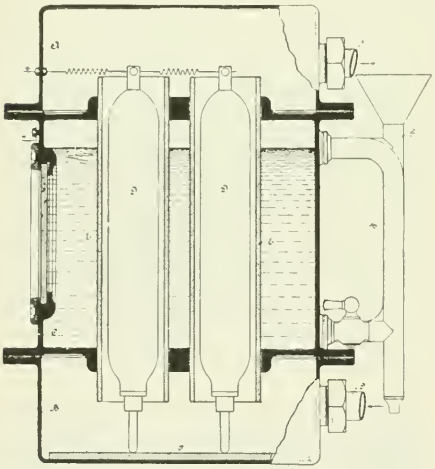


FIG. 2—OZONE APPARATUS.

plant is divided into two separate halves, and each half contains therefore 24 ozonizers; these are divided into three series, each of eight ozonizers, and each such series of eight apparatus is connected to the 8,000-volt secondary winding of a transformer. One such series of eight apparatus gives the ozone required for one sterilization tower. The ozonizers are of the Siemens tube type (glass at the one hand and metal at the other hand), one pole being earthed on account of the method of cooling the discharge surface with water. The ozonizer tubes are shown in Fig. 2, in which A and B are the upper and lower covers, while C is the middle part of the ozonizers. DD are connected to the positive pole, G and H are the tubes for the cooling water, and JJ are the tubes for the air.

The connections to the positive pole (the pole which is not earthed) are well protected, so that it is impossible for the attendants to touch them. Eight ozonizing tubes are contained in an iron box, the upper, lower and front sides of which are provided with thick glass windows. The ozonizer room is generally kept dark, and the attendant who enters it sees at once from the blue light passing through the glass windows of the ozonizer boxes whether the apparatus is working satisfactorily. As all metallic parts connected to the 8,000-volt pole are entirely protected, the attendant can only touch those parts which are connected to the other (earthed) pole, and there is no danger.

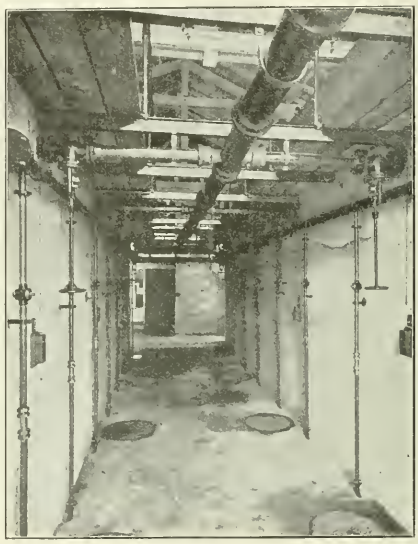


FIG. 3—STERILIZING ROOM.

The sterilizing room which is shown in Fig. 3, contains two series each of four towers of brick. Each tower is divided into four sections by two partition walls perpendicular to one another. A cross section of such a sterilizing tower which is about four meters (13 feet) high, is shown in Fig. 4. As

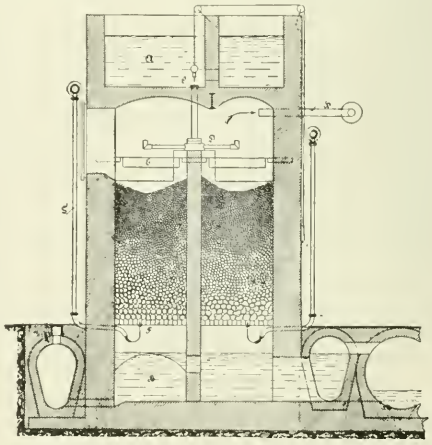


FIG. 4—CROSS SECTION OF A STERILIZING TOWER.

will be seen the tower is filled up to about two meters (6½ feet) with coarse-grained gravel through which the water is trickling down, meeting on its way the uprising ozone current. C is a device for stopping the run of water automatically whenever the operation is interrupted in some way. Through

each full tower (*i. e.*, through its four sections together) 42 cubic meters (11,100 gallons) are flowing downwards per hour, while in the same time 80 cubic meters (2,800 cubic feet) of ozonized air pass upwards. A is the basin containing the not-sterilized water, B the basin containing the sterilized water, EE are screens, G the tube through which the ozonized air is introduced and H the tube through which the air flows off.

Accidents can occur when the operation of the electric apparatus should be interrupted or the introduction of ozonized air to the sterilizing towers should cease, for some reason. Whenever this should happen very simple and reliable automatic devices are provided which prevent a further supply of not-sterilized water to the sterilizing towers.

For the operation of each half of the plant (sterilizing 125 cubic meters or 33,000 gallons of water per hour) 50 horse-power are required, of which 27 horse-power are used for the ozonizers, 22 horse-power for the pumps and 1 horse-power for various purposes.

The cost of the process at Schierstein is 0.35 cent per cubic meter of water, 0.1 cent being the cost of coal required for the operation of the ozonizing apparatus. To this must be added a charge for interest and amortization, which is about 0.15 cent, so that the total cost per cubic meter is 0.5 cent. It is to be considered that at the Schierstein plant power is required for operating pumps which is not necessary for any ordinary ozonizing plant.

Tests of the sterilized water, made by Prof. Proskauer and Dr. Schneider, and also other tests made in the Fresenius Institution, showed that the sterilization process by means of ozone is in every way successful, so far as the results—i. e., the annihilation of germs and bacteria—is concerned. The process is therefore well adapted for the purification of drinking waters.

A month after the Schierstein plant, the Paderborn plant

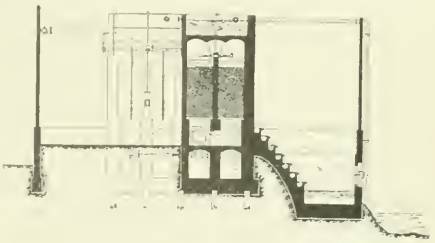


FIG. 5 STERILIZING TOWERS AT PADERBORN.

was opened. Its installation is exactly the same as that of the Schierstein plant, with the only exception of the sterilizing towers. They are illustrated in Fig. 5; the sterilized water is flowing off in form of cascades, so that the ozone dissolved in it is given off. The cost of sterilizing one cubic meter of water is in this plant about 0.4 cent, including charge for interest and amortization.

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

BY CARL HERING.

## INDUSTRIAL ELECTROCHEMISTRY.

*Conversion of Amorphous Carbon into Graphite.*—Those interested in the artificial production of graphite will find an interesting summary of the systematic work done by various investigators, in a recent paper by FITZGERALD, before the Franklin Institute, and published in the Journal of that society for November. Much work has been done in this direction, notably by Despretz, Berthelot, Moissan and Acheson. By the Acheson process the conversion of amorphous carbon into graphite is complete according to Berthelot's definition of graphite, as that form of carbon which on oxidation at low temperatures yields only graphitic oxide. The density is thereby increased considerably, the mean value of densities of six electrodes before graphitizing being 1.90, and after graphitizing 2.19. The electric conductivity is at the same time greatly increased, Lincoln having found the resistance of one cubic inch of an amorphous carbon electrode to be 0.00124 ohm and that of one cubic inch of graphite electrode 0.00030 ohm, that is about four times the conductivity. The purity of the graphitized carbon is greater than that of the amorphous from which it is made, for a greater or less quantity of the impurities is volatilized, the final purity depending on the temperature to which the carbon has been raised and the time expended in heating. A specimen of anthracite coal was analyzed and found to contain 5.783 per cent of ash. After prolonged heating and conversion into graphite the latter was found to contain only 0.033 per cent of ash. In summarizing the more important work done by the various investigators the author remarks that their results are by no means in agreement. Despretz in his experiments was endeavoring to show that carbon can be fused, welded and volatilized, and thought he had done so. Moissan, however, in his experiments never found any sign of fusion, and concludes that vaporization occurs without previous fusion. In some of his experiments at least, Despretz probably mistook the formation of fusible carbides for fusion of carbon. Despretz's conclusion that any carbon becomes proportionately softer as it is heated for a long time to a high temperature, is incorrect; for instance, the hardness of the ordinary manufactured carbon is increased by prolonged baking at a very high temperature; and some forms of anthracite coal may be so greatly hardened by heating for some time to a high temperature out of contact with air, that they will readily scratch glass. Berthelot's definition of graphite, as given above is perfectly satisfactory from the chemical point of view, but it is not always satisfactory in practice, for example some forms of carbon which come under his definition do not mark paper. The conclusion to be drawn from a comparison of Berthelot's and Acheson's researches seems to be that while all true graphites yield graphitic oxide, all bodies yielding that compound are not necessarily graphites suitable for practical purposes. In view of the fact that various kinds of hard and soft graphites produced by artificial means are now being put on the market, and that varieties of amorphous carbon (notably retort carbon) are also sold under the name of graphite, the author thinks it would be advisable to revise the nomenclature of carbons, reducing it to a more rational and practical form free from all ambiguities. The most interesting of Moissan's methods of transforming amorphous carbon into graphite, as compared with the commercial method, is the conversion by a simple elevation of temperature. While his investigations show clearly that heat has a most distinct effect in bringing about the polymerization of both carbon and graphite, yet, in view of Acheson's work on the remarkable part played by various carbide-forming sub-

resistance in effecting the transformation of amorphous carbon into graphite, some of Moissan's experiments are rigidly conclusive in demonstrating that the change is effected solely by elevation of temperature.—*Jour. Franc. Inst.*, November.

*Electrolytic Alkali Industry.*—To the literature on alkalies J. B. C. Kershaw contributes another article in the Lond. *Elec.* December 12th, which is the conclusion of his former illustrated one. He discusses the electrolytic alkali industry in the United States. He makes brief remarks on some American companies, but seems to give nothing new, nor is his review complete. Some general remarks on the financial conditions of the electrolytic alkali industry and the rivalry of the older Le Blanc process are added. It is said to be proved that a well-equipped Le Blanc alkali plant, using the Deacon process for decomposing its hydrochloric acid, can produce bleach at present at a cost below $17.50 per ton. The fall in the selling price of bleaching powder, while it will seriously curtail the profits of the Le Blanc works, will therefore not cause actual loss to the manufacturer, and therefore continued competition from this quarter must be expected by the electrolytic alkali companies. The author also gives data on the cost of the electrolytic process and finally reaches the conclusion that the total cost of 1 ton of 72 per cent. of caustic soda and 2.1 tons of 35.0 per cent. bleaching powder, by the best electrolytic processes, is about $70. The present selling value of the above amounts of these chemicals is, however, $110, and the 1903 value, when the drop in the value of bleach will have become effective, is $86.25. The prospects of the electrolytic alkali works are therefore not as hopeless as their rivals are disposed to believe; and although some of the companies may fail during the approaching period of competition, it is probable that the stronger ones will survive the ordeal, and that they will be benefited by this trial of strength with the old Le Blanc works.

The Lond. *Elec.*, December 9th, contains an official communication from the electrochemical electrolytic alkali works at Bitterfeld, Germany, to the effect that Kershaw's statement that the Aussig bell process is being used at one of the Bitterfeld works, is wrong.

*Statistical.*—Among the annual statistical information to be expected in this month is an article in the *Eng. and Min. Jour.* January 3d, by Schnattenbeck, on the chemical and allied mineral trades in 1902. In America rapid progress is being made in the manufacture of chemicals, notably those which have heretofore been considered entirely European products. The domestic production of alkali is growing steadily, and as prices are low and the quality of alkali good, imports have fallen over 60 per cent. in two years. Manufacturers of electrolytic caustic soda are proving hard competitors to sellers of the old process article, and imports are suffering severely from this competition. The consumption of bleaching powder is great, as is shown by the large imports and increased domestic production; prices are very low and "in fact, the prices accepted on new contracts are so low that it is impossible for the older works to compete with the modern plants employing electrolytic processes." The domestic consumption of bleaching powder is now about 75,000 or 80,000 tons a year, of which our own works contribute an increasing quantity, while Great Britain and Germany furnish the bulk of the imports. A feature in the trade was the appearance of the new electrolytic bleach made by the Solvay Process Co. of Belgium. Notes are also given on bicarbonate of soda, sal soda, chlorate of potash, chlorine gas, copper sulphate, sulphuric acid, nitric acid, muriatic acid, oxalic acid, carbon dioxide, brimstone, pyrites, alum, copperas, cyanide, cryolite, bromine, barytes, arsenic, zinc dust, bichromates, nitrate of soda, sulphate, ammonia and potash salts.

The same journal contains another by Struthers, on the production of minerals and metals in the United States during 1902. He gives a preliminary statistical table of the output in the United States during 1902. The grand total of the value of metallic and non-metallic substances produced in the United States from domestic ores during 1902, was $1,360,344,147, as compared with $1,198,938,697 in 1901, an increase of 13 per cent. for the year. The total value of metals was $569,149,785, as compared with $496,155,923, an increase of 15 per cent. The value of the production of non-metallic substances was $886,694,362, as compared with $796,411,855, an increase of 12 per cent. The production of aluminum was 7,300,000 pounds, valued at $2,284,590 (against 7,150,000 pounds, and $2,238,590 in 1901). The copper produced in 1902, was 669,855,006 pounds, valued at $78,630,453 (against 609,173,212 pounds and $87,300,515); 358 ounces troy of platinum were produced from domestic ores, and 674 ounces were recovered from South African ores; the quantity of platinum imported during the first eleven months of 1902 was 6,467 pounds (apparently avoirdupois), valued at $1,766,869. The output of zinc was 158,447 short tons, valued at $14,380,650. The output of carborundum was 3,800,000 pounds, valued at $324,058. The output of artificial graphite was 2,351,491 pounds, valued at $111,251. The quantity of sodium salts manufactured in this country was 528,000 tons, valued at $9,477,600. There are also special articles on antimony in 1902; copper, gold and silver, lead, nickel, platinum, tin, zinc, iron and steel, coal, and on progress made in metallurgy at various places.

## THEORETICAL AND EXPERIMENTAL.

*Electrolytic Conductivity.* Judging from the amount of matter recently published on this subject, it has received considerable attention lately, from various standpoints. With reference to theoretical questions, more especially the testing of the validity of the Nernst-Thomson rule, Kahlenberg and Schlundt have recently made some interesting investigations on the solubility, electrolytic conductivity and chemical action in liquid hydrocyanic acid, published in the *Jour. Phys. Chem.* for October. They are of special interest on account of the high dielectric constant of this solvent, thus making possible an exact examination of the Nernst-Thomson rule. The facts are, that while some salts dissolved in liquid HCN conduct electricity better than in water, many others conduct much worse than in their corresponding aqueous solutions. The acids as a class illustrate this in a very striking way; for while their aqueous solutions are most excellent electrolytes, their solutions in liquid HCN are only moderately good electrolytes in the case of hydrochloric and sulphuric acid, while the solutions of the organic acids are exceedingly poor conductors of electricity. In the face of these facts, the Nernst-Thomson rule can not be considered as substantiated by the conductivity of solutions in liquid HCN. The authors conclude that the conductivity of a solution is not determined by the dielectric constant of the solvent, its state of polymerization or its spare valences, but rather by the specific nature of the compound formed when solute and solvent act on each other to form the solution. For instance, the relatively high conductivity of amyl amine, strychnine and morphine in liquid HCN is worthy of note; these bases undoubtedly react with the liquid HCN, forming salts that dissolve in an excess of the solvent.

The influence of the solvent in electrolytic conduction has recently been investigated by Patten, the principal results being as follows: The lowering of the specific electric conductivity of non-aqueous solution by the addition of a pure solvent, is approximately proportional to the number of gram-molecules of solvent added; the application of this principle offers a new method of determining molecular weights. The curves of alteration of the specific electric conductivity are peculiar to each solvent; the alteration depends upon the chemical character of the solvent employed all degrees of this chemical influence of solvent on the original solution, being observed, from water to benzine. The idea is advanced that electrical conductivity is the resultant of, first, the tendency of some molecules to transfer the charge produced by an impressed e. m. f., and, second, the resistance offered to this

transfer of charge by other molecules. Konowalow's conclusion that the small molecular volume of water stands in a definite relation to the power of aqueous solutions to conduct electricity, is unwarranted; also his conclusion that the magnitude of the electrical conductivity of solutions is proportional to the intensity of chemical combination between solvent and solute, as measured by the heat effect. The conduction of electricity by solutions depends upon the fact that a compound is formed by the solvent and solute when solution takes place; and the degree of electrical conductivity depends upon the constituents in this compound, and possibly upon their arrangement. These investigations are described in the *Jour. Phys. Chem.*, November.

The limits of electrolytic conductivity were investigated by BONSFIELD and LOWRY, in a paper in which they point out that, quite apart from the limits due to freezing or boiling, electrolytic conductivity has another lower and an upper limit. At the lower limit the viscosity of the solvent stops the motion of the ions, and at the upper limit the solvent loses its ionizing power. The series of changes may be represented by a curve giving the conductivity as a function of the temperature; this curve has a maximum, depending on the nature of the solvent and solute as well as on the concentration of the solution, the conductivity being a maximum and the temperature co-efficient of the conductivity being zero at this point; as the temperature falls, the conductivity decreases, because the increasing viscosity more than counterbalances the effects of increasing ionization. Over a considerable range the curve follows an approximately linear law, this straight line becoming concave to the horizontal axis at the higher temperatures and convex at the lower temperatures. On this part of the curve the conductivity of the majority of aqueous solutions must be represented, the acids giving values on the concave and the salts on the convex part of the curve. At very low temperature the curve probably becomes asymptotic to the axis of temperature. Above the temperature of maximum conductivity the conductivity also decreases, the decreasing viscosity being now more than counterbalanced by the decreasing ionization of the solution. The decay of ionization becomes more rapid as the temperature rises, and if the solution is not an electrolyte *per se*, the curve runs steadily down and cuts the axis at the critical temperature of the solution. The paper is published in the *Proc Roy Soc.*, October 17th, an abstract of which is given in the Lond. *Elec.*, November 28th.

An account of experiments to determine the conductivity of concentrated solutions of sulphuric acid, caustic soda and calcium chloride, which have very low freezing points, is given by KUNZ in the *Comptes Rendus*, November 10th. With a 45 to 70 per cent. solution of sulphuric acid, temperature below 70° could be attained and measured by means of a constantan iron couple. His measurements show that the conductivities of all of these do not converge to zero (that is, infinite resistance) at —39°, as Kohlrausch supposed, but more likely at absolute zero, thus representing the reverse of the case of the pure metals, whose resistivities converge to zero at the same point. An abstract is given in the Lond. *Elec.*, November 28th.

*Aluminum Anode.*—The curious and somewhat mysterious behavior of aluminum as an anode, in that it stops a current from passing, and may therefore be used as a rectifier of alternating currents, is receiving some much-needed investigation, and the anomalous action is beginning to be more clearly understood. Although much was promised by such rectifiers some years ago, they have not been found practicable with the exception perhaps of the new form described last year by Burgess. Among the recent investigations of this behavior of aluminum is a (Brit.) Physical Society paper by TAYLOR and INGLES, an abstract of which is given in the Lond *Elec.*, November 28th. They begin by calling attention to the fact that aluminum is very slowly acted upon by dilute sulphuric acid even at moderately high temperatures, which with dilute hydrochloric acid the action is violent, and it is found that if a little hydrochloric acid or a soluble chloride be added to dilute sulphuric acid, the action is as violent as with hydrochloric acid of the same concentration. This peculiar phenomenon is thought to be connected with the other well-known fact that when an aluminum electrode is used as anode in a solution of a sulphate or of sulphuric acid, there is a very great resistance which does not exist when the aluminum plate is cathode or when other acids are substituted for the sulphuric acid; this great resistance is generally supposed to be due to an insulating film. The authors endeavor to explain both phenomena as being due to the same cause. They used a cell containing an aluminum and a platinum electrode in dilute sulphuric acid; they examined the influence of the addition of certain salts; the influence of potassium chloride, bromide, nitrate, acetate, chlorate and thiocyanate were thus investigated and the authors conclude that the presence of certain ions enables a large current to pass through the cell. They think the reason is that the film of aluminum hydroxide on the anode is permeable to certain ions but impermeable to others. The anomalous behavior in sulphuric acid would then be due to the impermeability of the film to the negative sulphuric acid radicle ions and also to the positive three-valent Al ions. This explanation is in agreement with the fact that a reversal of the p. d. acting upon the cell immediately causes a current to pass, the film being permeable to hydrogen ions. They made experiments on the rate of diffusion of various ions through a film of aluminum hydroxide, and found that several salts of potassium diffused rapidly through such a film, but the sulphate passed through very slowly. This strengthens the argument that the abnormal behavior of aluminum anodes in sulphuric acid is due to impermeability. It is suggested that the very small current which does pass may be due to a secondary action at the anode in which the ions of water take part. The theory is confirmed by a series of experiments in which the peculiarities of the aluminum anode are reproduced by means of a platinum anode coated with a film of aluminum hydroxide. A further test was applied in the direct measurement of the resistance of a film of aluminum hydroxide to the passage of different ions. Quantitative experiments which the authors have performed on the effect of the presence of different ions on the reaction between aluminum and sulphuric acid, show that this reaction is accelerated considerably by the addition of potassium chloride.

The theory of a rectifier based on this principle is given in a paper by Guthe, published in the *Phys. Rev.* for December. It has already been abstracted in the ELECTROCHEMICAL INDUSTRY for November.

*Depolarization by Potassium Chromate.*—MUELLER continues the description, in the *Zeit. f. Electrochemie*, December 11th, of his researches on the effect of soluble chromates in the electrolysis of aqueous solutions of the halogens, represented by a diminution of the reduction at the cathode. This latter influence may be shown by the following experiment: A 1 per cent. solution of potassium hydrate is saturated with potassium iodate and 200 cc. are put into the cell containing platinum electrodes, the anodic and cathodic department being separated from each other by a diaphragm. The current is regulated so that it is just below the point at which there would be development of hydrogen at the cathode; that is, there is perfect depolarization. If, then, 2 cc. of an aqueous solution containing 10 to 20 grams of potassium chromate in 100 cc. are added to the cathodic department, hydrogen begins to develope at the cathode, and at the same time the voltage at the terminals of the cell increases. This is shown to be due to the formation of a diaphragm of an insoluble chromium compound on the cathode. The increase of the voltage at the terminals is due to the fact that before the formation of the diaphragm there existed a strong depolarizer, but after the diaphragm becomes active, the electrolyte behaves as though no depolarizer was present.

*Residual Currents.*—While it is generally accepted as true

there is a definite minimum e. m. f. required to decompose a certain electrolyte, yet it is a fact that with any electrolyte, no matter how low the applied e. m. f. is, a current is found to pass; it may be small, but is measurable. This is what was called a "Reststrom" by Helmholtz, who worked with an e. m. f. of 1.1 volt and found that a measurable current passed for weeks at a time through an electrolytic cell with platinum electrodes in distilled water or in dilute sulphuric acid. His explanation is that the solution may originally contain dissolved hydrogen, then this hydrogen present at the anode acts as a depolarizer; at the same time an equivalent amount of hydrogen is liberated at the cathode and will either dissolve in the electrolyte or be occluded; although electrolysis takes place, neither of its products appear and the e. m. f. does not have to do the work implied by the decomposition of water into its components; in other words, a current may pass, although the e. m. f. is less than that required for decomposition; the hydrogen freed at the cathode may diffuse through the liquid until it reaches the anode and so by a constant circulation support the current. If, at the start, the solution or the electrodes contain oxygen instead of hydrogen, the reasoning will be analogous. This view of Helmholtz is supported by the fact that if the gases are artificially removed from the original electrolyte, the "residual current" is much smaller. Bigelow has now made very extended experiments in this same direction, the description of which he published in a long paper in the *Jour. Phys. Chem.* for December. These, he claims, show that Helmholtz's explanation cannot represent the whole truth. His experiments were made with platinum electrodes, and from the results he offers the following new theory: A dissolved gas is assumed to be in a condition analogous to a rarefied gas, some of whose molecules Thomson has shown are capable of carrying positive electric charges, other negative ones. The process of solution is assumed to be sufficient to occasion this differentiation. When a charged gas molecule comes in contact with the metal of the electrode, it gives off its charge; the molecule may then be occluded or remain in solution; in the latter case it increases the concentration of the neutral molecules and thus induces a further differentiation into molecules with opposite charge. If a small external e. m. f. is applied there will be a tendency for one electrode to attract positively charged molecules, and for the other to attract negatively charged molecules. Though the charge on the individual molecule is probably the same as that on the ion, the former are present in such small numbers that the total current carried by them is much less than that carried by the ions when the decomposition point is once passed, in fact negligible in all ordinary work. This theory enables one to say that there is a real and definite decomposition point for each pair of ions under given conditions; any current observed before this value is reached, being due to the charged molecules present. Unfortunately he used platinum plates, which have the property of combining with oxygen and hydrogen, and this necessarily limits his conclusions to such plates. Not until a material is used which is absolutely passive, can general conclusions be drawn.

*Formation of Ozone.*—Wakeling has recently investigated the production of ozone by discharges in a closed volume of oxygen. In this case the formation of ozone has a limit which varies with the conditions of the experiment. Besides the ozonizing effect there exists a contrary effect which counterbalances it after a time. Since for the limited duration of the ozonizing process the spontaneous decomposition of the ozone is negligible, it follows that the electric discharge itself must produce the contrary effect. In endeavoring to obtain a measure of both effects, he starts from the assumption that the ozonizing effect is proportional to the number of molecules of oxygen present, while the decomposition is proportional to the number of molecules of ozone present. There is a decided difference between the behavior of a positive discharge and that of a negative discharge; the maximum percentage of ozone is about three times as high for negative as it is for positive discharges. If, after the negative maximum is reached, the mixture is subjected to the positive effluvium, the percentage falls to the positive maximum. The decomposing activity is the same for positive and negative electricity, but the ozonizing action itself is three times higher for negative electricity. The effect of temperature on both discharges is the same. The results are given in the *Ann. d. Phys.*, November 12th, and abstracted in Lond. *Elec.*, December 19th.

*Electrolytic Oxidation of Organic Substances.*—An account of experiments on the electrolysis of formic acid and oxalic acid, also of potassium carborate, is given by Salzer in the *Zeit. f. Elektrochemie*, December 4th. His investigation is only preliminary, but shows the great difference in the reaction and especially in the anodic potential difference, when a bright platinum, as distinguished from a platinized platinum anode, is used.

*Crystallization from an Electrolyte.*—Heyl gives an account of an experimental investigation of this subject in the *Phys. Rev.* for December, in which after failing to find any effect produced by electrostatic stress upon the formation of crystals, he studied the effect produced on an electrolyte carrying a current, but again obtained negative results. Two substances were used, one was copper sulphate in an aqueous solution, and the other mercuric iodide in concentrated hot hydrochloric acid. The passage of the current produces no effect comparable with that produced by the heating of the solution.

*Alloys of Lead, Tin and Bismuth.*—A very long experimental investigation of the alloys of lead, tin and bismuth from the standpoint of the principles of physical chemistry, especially the phase rule, has recently been made by Shepherd. From alloys containing lead, bismuth and tin, he found that the pure tin crystallizes, but often in an unstable, denser form, and that lead and bismuth form two series of solid solutions, in each case with contraction. When the fused alloys are cooled fairly rapidly, the saturation concentrations are not reached. His researches are published in the *Jour. Phys. Chem.*, November.

*Electric Origin of Molecular Attraction.*—An attempt to reduce molecular action to the electron theory, has recently been made by Sutherland, in a paper in the *Phil. Mag.* for December. He starts with the conception of a neutral gaseous molecule, containing positive and a negative electron, and shows that there is a strong contrast with the law of gravitation; the first condition of the electron theory is satisfied by the fact that molecular mass does not enter into the expression for molecular attraction. It may be considered that the two electrons of a molecule like NaCl, when giving the line spectrum of sodium, revolve round one another in a circle of such size that centrifugal force and electric attraction are in equilibrium; perhaps they revolve entirely within the Na atom. An abstract may be seen in the Lond. *Elec.*, December 12th.

*Laboratory for Electrolytic Analysis.*—The first part of an illustrated description of the laboratory for electrolytic analysis of the Electrochemical Institute of Nancy, is given by Richard in *l'Eclairage Elec.*, December 13th.

## PRIMARY AND SECONDARY BATTERIES.

*Storage Batteries.*—The general problem of the storage battery, involving its possibilities and its future, has been the subject of numerous articles during recent years, and while there is a general similarity between them, and while the results of such opinions do not seem to have had any very beneficial effect, other, perhaps, than to discourage the investigation of radically new types, yet the views of recognized authorities are nevertheless of interest, even though the prophecies of experts do not always come true. Stated briefly, the opinions seem to exist that no other type of storage battery will be found than the present lead battery, and that this lead battery is not what is desired. To predict that nothing new will ever be found in a field where there is a possibility of an

infinite number of combinations of an almost infinite number of chemical materials, seems presumptive, and may not the general condemnation of the much abused lead battery be due largely to the fact that we expect more from it than is possible to obtain in practice? Many of the faults found with the lead battery may equally well be applied similarly to human beings; our life is limited and we resent abuse; yet we would not like to admit that we are complete failures.

The latest comments on the storage battery problem are by SWINBURNE, who, in his presidential address to the (Brit.) *Inst. Elec. Eng.*, discusses the problem of their design as follows: He believes that we are practically limited to lead, at any rate in acid cells. The plate which is anode during discharge should not dissolve in the electrolyte, for if it does the deposition and solution will be uneven, and the plate will grow trees and comes to grief. This excludes zinc and iron unless a suitable electrolyte is found. On the other plate an insoluble depolarizer is needed, or else a double fluid cell must be used, involving a porous diaphragm, diffusion and impracticability. Not only must the depolarizer be insoluble, but it must be converted into an insoluble body on discharge. The coating must be a conductor in one state or the other, or there will be no proper contact. In the lead cell there is always enough peroxide and metallic lead in the coating to secure electrical contact though the discharge product is an insulator. The depolarizing coating must be connected to a conducting plate which is not attacked by local action. Lead and silver are the only available metals, and sulphuric and perhaps phosphoric, the only acids, for the nitrate of lead is soluble and hydrochloric acid is decomposed by lead peroxide. Lead is protected by its coating of sulphate or peroxide, as the case may be. "It thus seems as if we were limited almost absolutely to lead and sulphuric acid. It is wonderful that we have the lead cell at all. We owe it to the chance observation of Planté. The theory was not understood for a long time. For many years it was thought that the pressure was due to the $PbO_2$ and Pb, changing into PbO. The acid was merely put in to make the electrolyte conduct, and sulphuric was used because people used it in gas voltmeters, and they never thought that it ought to be as strong as practicable to give the pressure and output. The difficulty of lead sulphate was regarded as a difficulty to overcome." What is wanted in the lead cell, is lightness, large capacity, cheapness, rapid discharge, efficiency and mechanical strength and durability, but these qualities are mostly antagonistic; large capacity means rapid deterioration, mechanical strength means weight, therefore, no use in testing a cell for capacity without testing the efficiency and durability too, published battery reports are often misleading, because they omit essential information. In alkaline cells, although the e. m. f. is smaller, the metals admit of light plates and grids, and the coating may conduct in both states, instead of in only one as in lead cells, so that a larger proportion of the coating may be active. "The future of this type of cell is uncertain, as very little has been published as to results." This part of his address will be found reprinted in the Lond. *Elec.*, December 19th.

*Dry Cells.*—ZACHARIAS, who has written on similar subjects before, believes that the manufacture of dry cells has passed through a state of rapid development in the last two years, especially in the production of very small cells which are very useful for pocket lamps for physicians, travelers, for use in the army, etc. In the ordinary dry cell he claims that not one quarter of the depolarizer is consumed under ordinary circumstances, while in cells of small dimensions the efficiency is better. In general, cells of two sizes are made, the larger one is 70 mm. high and has a cross section of 35 mm. in square; the smaller one is 55 mm. high and has a diameter of 20 mm. Three such cells, sufficiently insulated from each other, are generally put together and surrounded by a card-board cover. The small incandescent lamps are generally provided with a reflector and a lens, and consume 0.25 to 0.3 ampere at 3.5 to 4.0 volts. One cell of the smaller size has driven an electric clock for four weeks, the current being 7 milliamperes. The author urges that in installing electric bells, etc., in houses, the proper dimensions of the wires should be chosen; that is generally not done in practice and much power of the dry cells is wasted. The carbon rods of the small cells are about 6 to 7 mm. thick and the surrounding depolarizing mass has a diameter of 14 to 16 mm.; it is held in position by four small glass tubes, for the sake of proper insulation from the zinc electrode. The distance between depolarizer and zinc electrode is only 1.5 to 2 mm. The electrolyte is to be filled into the space between the zinc and the depolarizer in a thick but easily flowing form, and is afterward made less liquid by special means. Even the best of these small cells, when continually used to light a lamp, last only fifteen minutes, they should therefore be used only momentarily, but notwithstanding this they are very useful for various purposes. His article is in the *Centralbl. f. Accum.*, December 1st and 15th, where he also gives some notes on testing such small dry cells.

## MISCELLANEOUS.

*Capillary Electrometer.*—In many electrochemical researches the voltages to be measured are very low, of the order of one volt or less, and for such low voltages the usual forms of voltmeters are not, as a rule, satisfactory. Moreover they require quite a perceptible current, which is the very thing that one wants to avoid in any electrochemical measurements. The capillary electrometer, therefore, is of special interest for such researches, as it takes no current at all, and its total range is within about one volt.

The following description of a new form by BURCH, abstracted from his Royal Society paper, reprinted in the Lond. *Elec.*, December 19th, will therefore be of interest. Fig.

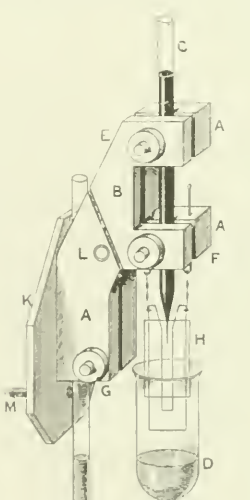



FIG. 1.—CAPILLARY ELECTROMETER.

1 shows the instrument in its final form and Fig. 2 shows the details of the capillary through which is the essential part. The support A is cut from a solid block of ebonite 9 cm. long, 5 cm. wide, and 2 cm. thick; the capillary tube is C. Adjustments for setting the capillary tube at right angles to the optic axis and parallel to the slit of the photographic recording apparatus, are provided for by the stout brass plate K; the screw M fastens it to the adjustable stand of the pro-

rectangular microscope. The brass plate K is so shaped that there is a space of about 3 mm. between it and the left-hand side of the ebonite support A, in order to leave room for the adjustment of the latter about L as a center. The construction of the capillary trough is shown in the diagrams, Fig. 2.

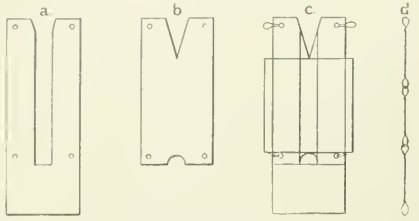



FIG. 2.—CAPILLARY ELECTROMETER.

*a*, *b*, *c*. A piece of mica, such as is used for lamp shades, is cut to the shape *a* with a pair of scissors; four holes are drilled with a needle in the positions shown, and a thin piece of the best clear mica is then selected, the piece *a* placed on it, and four corresponding holes pricked through with the needle, the piece being afterwards cut to the shape *b*. Finally, *a* and *b* are fastened together by four little loops of No. 30 platinum wire, and the whole trimmed to shape with the scissors. The trough is then hung by two platinum chains; these are made of No. 30 wire, with long links, as shown at *d*, Fig. 2, so that the acid may not creep up them; they are hung from the hooks shown in Fig. 1, which are best made of half-round wire, doubled like a linch-pin, sliding easily but firmly in holes on each side of the capillary tube, as shown in Fig. 1. The operation of putting in a capillary is as follows: The instrument is fixed to any convenient support by the screw M; the milled head G is loosened, and the U tube drawn down and turned aside; the whole instrument is then tilted backwards to an angle of 45° from the vertical; in this position the trough H hangs clear of the capillary tube; if the capillary tube has already been filled and connected with the pressure tube, the nuts E and F must be unscrewed far enough for the tubes to pass sideways into the clamps, but a new capillary may be easily and safely inserted from below after merely loosening E and F. It must then be filled to within 2 cm. of the top, but not nearer, with recently distilled mercury from a perfectly clean pipette; it is then connected with the pressure apparatus, and some mercury forced through. The screw M is then slightly loosened, and the instrument raised cautiously to a nearly vertical position. The trough H is adjusted by sliding the hooks up or down, or bending them until the capillary rests against the center of it, the apparatus being tilted back during each alteration. When these adjustments have been made, the inside of the trough is wetted by touching it with a glass rod dipped in dilute sulphuric acid of 25 per cent., and the apparatus is tilted forwards until the wet trough swings against the capillary and sticks to it. A piece of thin cover glass, or mica, if very high powers are to be used, slightly wider than the trough, wetted on one side with the acid, and placed carefully against the trough, to which it adheres, holding it firmly against the capillary, the lower edge of the glass resting against the platinum loops with which the trough is fastened together, as shown in Fig. 2, *c*. The U-tube is then turned back into position, cautiously raised until the lower edge of the glass just dips into the acid, and clamped by the screw G. Finally the trough is gently shaken or pushed to and fro in the plane of the mica, until the acid rises in it to the required height and all the bubbles are expelled. The definition, with these electrometers, is perfect. The capillary touches the cover-glass throughout its length, so that any dry objective can be used. The microscope should not, however, be left focussed on the capillary, lest the acid should by chance get between the objective and the cover-glass.—Lond. *Elec.*, December 19th.

*Sewage Purification.*—An account of experiments made at Salford with various processes of purifying sewage electrically, by Corbett, is given in Lond. *Engineering*, December 26th. The requirements at Salford are governed by the fact that the sewage to be treated is that of a manufacturing town of nearly 250,000 inhabitants, where trade wastes in great variety are admitted to the sewers, and where a large quantity of mere land water enters the sewers also. Among the processes tried was Webster's electrolytic process, and it is said to have been in many points the most unique and most successful of the processes experimented with. Its cost was somewhat high, though by no means the highest considered practicable, and it would have been adopted for the Salford sewage works but for the inability of the company promoting it to finance so large a scheme. In this process no chemical precipitants are used, but "the sewage is passed between cast-iron plates, alternately connected with the positive and negative wires of a dynamo. The effect of this is much like that of chemical precipitants, the sewage being separated into clear liquid and flocculent particles, which subside into sewage sludge in ordinary precipitation tanks." The tank effluent is clear and non-putrescible, but contains fine particles of sesquioxide of iron which give it a rust tint, and this can be readily removed by rapid filtration through a fine sand and gravel filter, the result being a perfectly bright and almost pure filtrate. About half the cost of working is for power to produce the electricity required; this process might therefore be cheap in a place where water-power is available. The company's offer was to treat the Salford sewage for twenty years at $15.06 per million gallons, they providing all the plant, etc., and the plant to be transferred at a valuation at the end of the term. In an appendix the following figures are given concerning this process. The requirements per million gallons of sewage treated per day were as follows: steam engines of 41.76 indicated horse-power; electric horse-power therefrom 33.4; average voltage employed, 41.02; iron used from the electrodes, 428 pounds (this equals about 3.2 grain of iron per gallon).

*Niagara Falls.*—Illustrated articles on the new plant of the Canadian-Niagara Falls Co. are given by Dunlap in the *Sc. Am.*, December 6th, and *Eng. News*, December 11th.

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl.

ELECTRIC FURNACES AND FURNACE PRODUCTS.

*Electric Furnace.* A. A. Shade, Chicago, Ill. Patent No. 713,923, November 18, 1902. Application filed December 28, 1901.

The specification describes an electric furnace intended for smelting or reducing ores and other fusible substances. It belongs to the type of electric arc furnaces, and the vertical cross section given in Fig. 1 shows three arcs arranged one above another, $D_1D_1$, $D_2D_2$ and $D_3D_3$. The shaft of the furnace is constructed in a peculiar manner, with projecting ledges and corresponding recesses below the electrodes, for the purpose of retarding the fall of the material and exposing it more thoroughly to the heat of the arcs, which are deflected towards the ledges by means of magnets $E_1E_1$. Another magnet $E_2$ is arranged

below the crucible C, so as to deflect the arc between $D_4$, $D_5$ into the crucible. The material is fed into the furnace through hopper $J_2$ and pipe B, and while passing through the conveyer it is dried in the chamber K, which is heated by the waste gases of the furnace, entering through pipe $K_1$. The body of the furnace is surrounded by a metallic casing $A_2$, held together by iron bands A, and the space between the body of the furnace and the casing is filled with insulating material $A_4$, as mineral wool, asbestos, etc. The electrodes are insulated from the casing by insulating rings $A^3$, and are supported in a sliding yoke G. They can be moved forward by means of hand wheel $G_2$ and spindle $G_3$, which bears against a cap fitted to the end of the electrodes. Shields F are provided below the magnets in order to confine the action of the magnets to the arc above them, and to prevent them from influencing the arc below. The crucible C is arranged so that it can be withdrawn from the furnace if necessary. $A^5$, $A^5$ are peep holes between the electrodes and on a level with the respective ledges. $A^1$, $A^1$ are passages in the walls of the furnace,

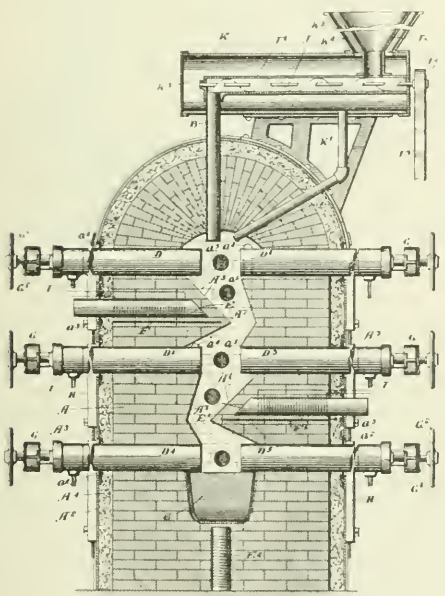


FIG. 1.—SHADE ELECTRIC FURNACE.

intended to permit the furnace gases to pass upwards through the furnace without being required to pass through the arcs.

*Electric Dental Furnace.* A. M. Hewett and J. C. Smith, Chicago, Ill. Patent No. 714,373, November 25, 1902. Application filed February 17, 1902.

The furnace is a portable one, constructed of an outer and inner muffle of fire clay. The inner muffle is provided with a screw thread on the outside, for the purpose of providing a seat for the heating coil.

*Electric Furnace.* H. N. Potter, New Rochelle, N. Y. Patent No. 715,505, December 9, 1902. Application filed November 21, 1901.

This furnace is an improvement on the inventor's former patent, No. 652,640, of June 26, 1900, in which the main source of heat was an electrolytic tube composed of a mixture of dry electrolytes and supplied with terminals for conveying electric current to the tube, which is kept in a state of incandescence by the current after a preliminary heating by external means. The present invention relates to providing means for preventing the current in such a tube from flowing unevenly, by reason of almost unavoidable slight differences in specific resistance of the tube, due to structural, and perhaps chemical, irregularities in the tube material. These difficulties are overcome by notching the tube, or building it up of alternate sections of relatively good and relatively poor conductors, or by imbedding rods of the good conducting material in a jacket of poorer conducting material. The mixture of dry electrolytes referred to above is a mixture of magnesia and alumina, and as poorer conductors, pure magnesia or pure alumina are proposed. The unmixed electrolytes being poorer conductors than the mixtures, the current will pass along the better conducting segments.

*Electric Furnace.* H. N. Potter. Patent No. 715,506, December 9, 1902. Application filed November 21, 1901.

The furnace consists essentially of a single carbon tube, lined with magnesia and coated with the same substance, surrounded again by a jacket of calcium oxide, the whole being then inclosed in a larger tube of glazed stoneware. The specification deals mainly with the mechanical means adopted to meet the problem of the expansion and contraction of the parts of the tube, which are alternately heated and cooled, and for which provision has to be made, on account of the intense heat at which the furnace is to be run. Moreover, as the material proposed for the jacket—namely, calcium oxide—is a hygroscopic substance, subject to slacking, means have to be provided to protect it, which is done by arranging a stuffing ring at or near the air inlet, in such a position that it will absorb moisture from the indrawn air and can be itself rapidly removed if necessary. Other materials of a heat-insulating and refractory nature, such as chalk, asbestos, etc., can be substituted for calcium oxide in the jacket.

*Tubular Electric Furnace.* H. N. Potter, New Rochelle, N. Y. Patent No. 715,507, December 9, 1902. Application filed February 7, 1902.

The same inventor declares in this specification that a carbon tube furnace is subject to sagging or warping out of shape under the influence of extreme heat, the carbon becoming plastic at the high temperature reached in the furnace, while other substances, such as magnesia, which are also used to form the body of such furnaces, are still more subject to distortion of shape under the influence of heat. The means proposed to overcome this difficulty consist in a series of carbon collars surrounding and supporting the internal tube throughout its length, the collars extending from the tube at right angles into a region which is much colder than that next to the tube. The construction does not interfere with the use of a jacket, as described above, as the carbon collars extend into or through the jacket. The whole structure, including the jacket and the collars, is then inclosed in a jacket of non-conducting material, *i. e.*, glazed stoneware, as referred to above.

*Electric Furnace.* H. N. Potter, New Rochelle, N. Y. Patent No. 715,508, December 9, 1902. Application filed March 27, 1902.

The inventor says: "In an application filed by me on November 21, 1901, I show and describe a lined carbon furnace tube, in which the tube rotates about its axis in order that the melted lining material may flow evenly over the inner surface of the carbon tube, while that invention also contemplates the rotation of the furnace tube for other purposes, as when metallic chromium is produced by a continuous operation and the material is worked steadily through the furnace, partly by the effects of the rotation of the tube. The present invention contemplates making the furnace of a double tube." Provision is therefore made to have the main carbon tube stationary and to arrange inside of it a comparatively thin-walled tube, which is to be revolved. By this means it is possible to renew the inner tube very easily. Connections to the main tube are much less complicated than if it rotated, and the space between the two tubes can be filled with an inert gas. The

inner tube may either be of carbon or of a material such as magnesia, zirconia, or the like. For operations such as tempering steel, firing enamel and melting alloys, the advantages of having an inner rotating refractory tube can be secured without the use of the latter by merely having a rotating magnesia lining, the temperature not being sufficiently high to cause the lining to adhere to the carbon furnace walls.

*Lead Support and Circuit Terminal for Carbon Tube Furnace.* H. N. Potter, New Rochelle, N. Y. Patent No. 715,509. Application filed March 28, 1902.

This patent describes improved means for making electrical terminal connections with carbon tube furnaces, and for mounting such furnaces in such a manner as to permit expansion and at the same time provide good mechanical support. The means employed for this purpose are metallic diaphragms at each end of the carbon tube; these diaphragms serving also as parts of the electrical connections at the ends of the furnace tube.

*Process of Obtaining Metallic Aluminium or Other Metals by Electrolysis.* Girolamo Taddei, Turin, Italy. Patent No. 715,625. December 9, 1902. Application filed July 17, 1901.

This invention relates to a process for obtaining metals from their compounds, and particularly the metal aluminium from its oxide, and the object is to effect this with the minimum of energy thermoelectrically considered in relation to industrial conditions, and to effect it in an automatic, or substantially automatic, and continuous sequence of steps or operations. Fused sodium chloride is first decomposed by electrolysis, and its elements are obtained in the form of vapors, the temperature being about 1,000° C. and the voltage about 4.5. The chlorine vapors are then introduced into a vessel charged with balls formed from a mixture of tar and dehydrated alumina, in which the proportions of the ingredients are as 6 of carbon to 9.1 aluminium. This vessel and its contents are heated up to from 1,300° to 1,500° C., and the chlorine, as it is gradually brought in contact with all parts of the mass, produces a reaction, resulting in the formation of aluminium chloride and carbonic oxide, according to the equation $Al_2O_3 + 3C + 6Cl = 2AlCl_3 + 3CO$. The aluminium chloride from this reaction, being in the state of vapor, passes, together with the carbonic oxide, into another vessel, where it comes into contact with the sodium vapor generated by the electrolysis of sodium chloride in the first step of the operation. Here another reaction takes place; the sodium combines with the chlorine of the aluminium chloride and sets free the metallic

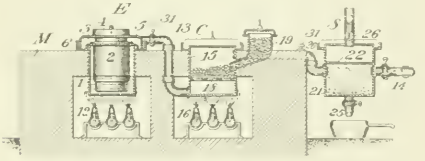


FIG. 2.—SECTION OF ALUMINIUM APPARATUS.

aluminium, $2AlCl_3 + 6Na = 3CO = 6NaCl + 2Al + 3CO$. Thus, says the inventor, the metal aluminium is separated, the sodium chloride is recovered without loss for use again and the carbonic oxide passes off and may be burned. The operations are continuous, the mixture of alumina and tar producing continuously aluminium and carbonic oxide. The sodium and chlorine, separately and in combination, move in a closed circuit without waste or being consumed. The accompanying Fig. 2 gives a longitudinal vertical section of the apparatus in which the process is to be carried out, and Fig. 3 represents the plan. The whole apparatus is set in masonry M, and is divided into three sections, the electrolysis taking place in E, the chlorination in C and the substitution in J. Section E consists of a vessel 1, into which depend separator tubes 2, fixed at their upper ends in an inner cover 3. The carbon anodes 4 depend in these tubes from an upper or outer cover 5, above the cover 3. The edges of the covers rest in a trough 6 around the vessel 1. At the side of the vessel 1, and connecting with it by apertures 7, is a vessel 9 for introducing the electrolyte or making additions during the process. The cathodes are of iron, and situated between the anodes; they are not indicated in the figures. From the space between the covers 3 and 5 two pipes 13 lead to the chlorinating section C, and pipe 14 leads from the interior of vessel 1 to the substituting section S. Section C consists of a vessel 15, divided into two chambers by a transverse partition, each chamber having a false perforated bottom, below which the chlorine enters. Raw material is introduced through hoppers 19, and pipes 20 lead to

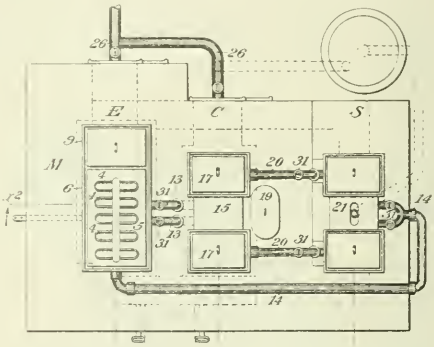


FIG. 3.—PLAN OF ALUMINIUM APPARATUS.

section 5. This section comprises a vessel 21, divided transversely by a partition 22 into two chambers, with covers 23. In each chamber there is also a horizontal partition 24, which extends from partition 22 part way across the chamber. Pipes 20, from vessel 15, and forked pipe 14, from vessel 1, enter below the partition 24. A pipe 26, with forked connection to the chambers in vessel 21, carries off the gases (CO) to the burners 12 and 16. The process is carried out by electrolyzing sodium chloride in vessel 1, the chlorine passing out between the covers 3 and 5 and through pipes 13 into vessel 15. There it acts on the mixture of alumina and tar, and the aluminium chloride and carbonic oxide produced in the reaction pass through pipes 20 into vessel 21, where they meet the sodium vapors conveyed from vessel 1 by pipe 14. Reaction takes place, metallic aluminium and sodium chloride being precipitated, and carbon monoxide escapes through pipe 26 and is led underneath the vessels 1 and 15, where it is burned. In order to separate the aluminium from the sodium chloride, it is proposed to put the mixture into the vessel 9 of section E, where the sodium chloride melts and replenishes the electrolyte, while the aluminium falls to the bottom and may be drawn off. The above process has been outlined at such length on account of the importance which would attach to any new method by which the cost of production of aluminium could be reduced. When it is compared, however, with the simple methods which are in use at present, it does not appear as though such an involved process, with its complicated apparatus, would be likely to accomplish a reduction in the cost of production.

*Apparatus for Obtaining Metals by Electrolysis.* G. Taddei, Turin, Italy. Patent No. 715,626, December 9, 1902. Application filed December 13, 1901.

This patent covers the apparatus used for carrying out the process described above. The wording of the specification is almost exactly the same as that of the preceding one, and nothing new is disclosed as to the nature of the material of which the apparatus is constructed. Anybody who has ever attempted to electrolyze sodium chloride, even at much lower

temperatures than are given by the inventor, knows how quickly metallic, as well as clay and porcelain, vessels are destroyed if they are heated from the outside. Furthermore, it is also well known that the higher the temperature of the electrolyte, the worse the yield of sodium (Borchers, "Electrometallurgie," p. 60).

*Carbophosphide of Calcium.* C. S. Bradley, Avon, N. Y., and R. H. Read and C. B. Jacobs, East Orange, N. J., assignors to the Ampère Electrochemical Co. Patent No. 710,812, December 16, 1902. Application filed April 20, 1898.

The new product described is obtained by heating a mixture of definite proportions of normal calcium phosphate, burnt lime or limestone and carbon in an electric furnace. The ingredients should be well mixed, and, with a mixture of two molecular

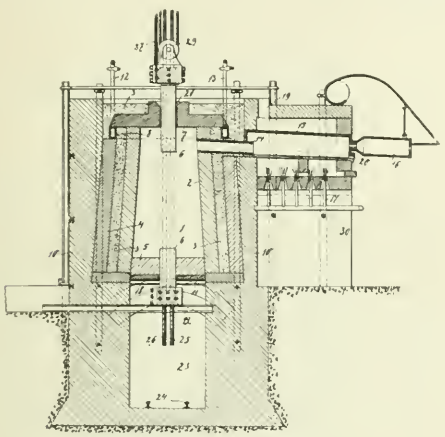


FIG. 4—DORSEMAGEN FURNACE.

equivalents of burnt lime, one of normal calcium phosphate and sixteen of carbon, reaction is stated to take place at the high temperature of the electric furnace, according to the equation $2CaO + Ca_3(PO_4)_2 + 16C = Ca_3C_2P_2 + 10CO$. The material is obtained in a stable, fused mass, which may be tapped from the furnace and allowed to cool, and is described as a homogeneous mixture of carbide and phosphide of calcium, the union of the two materials being analogous to that in the case where two or more metals unite to form a homogeneous alloy. The material, when treated with water, decomposes, yielding a gas which contains acetylene, gaseous phosphide of hydrogen ($PH_3$) and liquid phosphide of hydrogen ($P_2H_4$) or its vapor. The presence of the last body renders the whole mixture spontaneously inflammable, so that if it is thrown into water or brought in contact with a wet surface gases are generated at once and burst into flame. The product is stated to be useful as a weapon of war. For instance, in naval warfare, when it can be projected into the vicinity of the enemy, and on coming in contact with the water a large amount of inflammable gases will be generated, which will at once ignite and force the enemy to retreat.

*Working Zinc and Substances Containing Silicic Acid in Electric Furnaces.* Alfred Dorsemagen, Wesel, Germany. Patent No. 716,008, December 16, 1902. Application filed August 24, 1901.

The inventor of this process has conceived the idea of uniting the production of carbide of silicon (carborundum) with that of metallic zinc by subjecting either naturally occurring siliceous zinc ores, as willemite, or artificial mixtures of roasted zinc ores and arenaceous quartz, mixed in suitable proportions with anthracite coal, to the heat of the electric furnace. In accordance with the equation $Zn_2SiO_4 + 5C = 2Zn_2 + SiC + 5Co$, carborundum is produced, and metallic zinc vapors given off. The operation is carried out in the furnace illustrated in Fig. 4, where 1 designates the furnace shaft, with side walls 2 and bottom 5 of carbon bricks. A layer of very fine sea sand 4 is rammed between the carbon lining 2 and the fire-brick work 4; 6, 6 are the carbon electrodes, between which a core of coke is rammed when the furnace is charged with the ore and coal mixture; 14 in an outlet tube for the zinc vapors; 15 and 16 are condensing chambers for the zinc vapors; 23 denotes a chamber in the bottom of the furnace, intended to accommodate a car, into which the material discharged from the furnace can be received. The process looks as though it was a very expensive one, as far as zinc is concerned, but perhaps the latter is only to be considered as a secondary product, the main product being carborundum. It does not look as though the inventor intended to separate the crystalline from the amorphous carborundum, as Mr. Acheson does, for the furnace does not look as if it was designed to be dismantled after each operation.

*Tap-Hole Plug.* Andrew Dickey, Buffalo, N. Y. Patent No. 714,159, November 25, 1902. Application filed December 2, 1901.

The specification describes a tap-hole plug, especially designed for closing the tapping hole in pots for the reduction of aluminium, where metallic or clay plugs cannot be used, owing to the contamination of the aluminium by the metal of the plug or the silicon of the clay. The plug consists of wood sawdust or paper pulp, either compressed with a suitable binder, like paste or size, or of paper wrapped in layers, the object being to produce a plug of carbonaceous material, such as cellulose, which will, when heated, be converted into a porous, friable charcoal, and which can easily be removed, if desired, without necessitating the use of drilling tools, etc., thus avoiding the danger of injuring the carbon lining of the melting pot. The green plug is placed in the tapping hole, and is converted into charcoal at its inner end by the molten material, but, on account of the low heat conductivity of the material, the carbonization only spreads very slowly to the other parts of the plug.

## APPARATUS AND PROCESSES FOR THE ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

*Process for Precipitating Metals from Solutions Containing Same.* T. Muffly, Bowdre, Ga. Patent No. 714,590, November 25, 1902. Application filed January 22, 1902.

The object is to provide an improved process for precipitating metals from solutions of alkaline cyanides, bromides, chlorides and hyposulphites or, more particularly speaking, for precipitating gold and silver from solutions of cyanide of potassium, by which said metals have been dissolved out of ores and the like. The novelty of the invention consists in the construction of the electrolytic vessel and of the cathode. The vessel shown in Fig. 5 is divided into two unequal compartments *a* and *b* by a partition *c*. In the compartment *b*, and right against the partition, is placed the anode *e*, of iron platinum, etc. The cathode *j* consists of a cellular porous carbon plate *g*, placed between two cellular porous carbon casings *h* and $h^2$, composed of carbon derived from the destructive distillation of tar, resin, oil etc. Between them is placed a packing *i* of filiform lead and zinc composition, consisting of an alloy of 20 parts of lead to 80 parts of zinc. The carbon plate *g*, casing *h* and $h^2$ and filiform packing *i* are inclosed in a cover $g^2$ of cotton cloth. Between the anode *e* and the

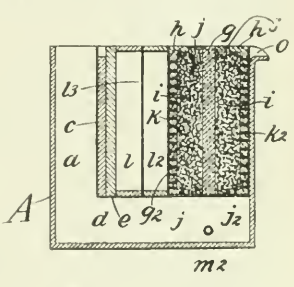



FIG. 5—GOLD DEPOSITION TANK.

cathode *f* is a space inclosed by frames *l* and $l_2$, of glass, porcelain or other non-conductor, and between these frames is preferably placed a screen *F*. Five such boxes are arranged, each having an independent battery of its own, and the electrolyte flows from one to the other. A perforated pipe *i* is arranged under the cathode, by which either hot or cold air is blown into the apparatus. After the electrolysis is finished, the carbon plate *g* and carbon casings *h* and $h^2$ are incinerated, the ashes containing the gold and silver are added to the product of the filiform packing *i* and the product smelted into bullion. The purpose of the glass or porcelain frames *l* and $l_2$ is explained by the inventor as follows "In limiting the electrolytic field between the electrodes *e* and *f* in one compartment *b*, with independent electrical connections with the battery, I secure a more perfect polarization of the solutions. By confining the electrolytic field within the insulating frames *l* and *F*, with the fabric filter screen between them, I prevent floating non-metallic precipitates at the anode *e* from passing through and corroding the cathode *f*, which results in a purer gold and silver product and more effective chemical action. In this method as a whole I secure a perfect and constant polarization of the compound molecules of the solution and a more rapid and complete deposition of the gold and silver atoms at the cathode."

*Apparatus for Separating Metals from Solutions Containing Same.* T. Muffly, Bowdre, Ga. Patent No. 714,598, November 25, 1902. Application filed January 22, 1902.

This specification is nearly identical with the preceding, and claims specifically the apparatus described above.

*Process of Electrolytic Separation of Copper and Nickel.* David H. Browne, Cleveland, Ohio. Patent No. 714,851, December 2, 1902. Application filed January 27, 1899. Renewed September 19, 1902.

The process consists in the electrolysis of a solution of cuprous and nickel chlorides. This is prepared by placing copper-nickel fragments into a long, narrow receptacle and simultaneously subjecting it to the action of a solvent for cuprous chloride, such as salt water, introduced into the top of the aforesaid receptacle, and a stream of chlorine introduced at the side of the receptacle. The chlorine is the product of a later operation. The combined action of the salt water and of the heat produced by the combination of the chlorine with the copper nickel alloy are said to form a solution of cuprous and nickel chloride, which is run into an electrolytic cell. Here it is electrolyzed between copper-nickel anodes and (presumably copper) cathodes. The cuprous chloride is said to be decomposed, the chlorine combining with the copper-nickel alloy of the anode to form cuprous chloride and nickel chloride again. In this manner all the copper is "plated out," and only nickel chloride remains, which is drawn off and freed from iron and traces of copper by precipitation with caustic alkali. The liquor is then heated to a temperature of between 30° and 60° C., concentrated to 30° to 50° Bé, and electrolyzed in a cell with a nickel cathode and a carbon anode, placed in a porous diaphragm. The chlorine given off here is utilized, as mentioned above, for obtaining fresh electrolyte.

*Anode.* F. McDonald, Johnsonburg, Pa. Patent No. 715,684, December 9, 1902. Application filed April 7, 1902.

The invention relates to anodes for electrolytic apparatus designed for the electrolysis of metallic salts, the object being to provide an anode simple of construction and advantageous in widely diffusing the current without undue heating. The anode consists of a tube of glass, or other suitable insulating material, filled with mercury, into which the positive wire is introduced at the top. A number of platinum strips are fused into the lower part of the tube, and it is stated that, in a vessel about 5 feet long, 12 inches wide and 12 inches deep, these strips will be preferably 10 inches long and 2 inches wide. This anode seems to be somewhat expensive for the electrolysis of metallic salts.

*Electrolytic Apparatus.* Joseph Matthews, Kings Heath and William Davies, Selby Park, England. Patent No. 715,281, December 9, 1902. Application filed March 29, 1901.

The apparatus is designed for stripping tin from scrap-tinned metal and depositing it on the cathode. It consists of an outer metallic tank, which at the same time serves as cathode and an inner circular-bottomed tank, insulated from the outer tank. The bottom and sides of the inner tank are formed of perforated insulating material, and the scrap metal, which is introduced in the inner tank and forms the anode, is constantly agitated by the radiating arms of a revolving drum, located in the inner tank. The electrolyte consists of caustic potash and protochloride of tin, heated to a little under the boiling point. Provision is also made for using independent cathodes.

### STORAGE BATTERIES.

*Storage Battery.* S. Laszczynski, Berlin, Germany. Patent No. 714,201, November 25, 1902. Application filed February 23, 1901.

This invention is stated to be an improvement in the construction of zinc-alkali storage batteries. A frame or grate, or any suitable form of electrodes, is pasted with zinc sponge, zinc oxide or zinc combinations in the same manner as with lead-sponge plates. Instead of employing zinc plates for the carrier frame, it may be made of amalgamated iron or nickel plate, or other suitable plate. A number of electrodes thus formed are mounted to alternate with nickel oxide plates, being separated from the latter by a piece of parchment only, the electrode block thus formed being then placed in a receptacle exactly large enough to contain it. As electrolyte, a solution of potassium or sodium aluminates, in which the zinc oxide is insoluble, should be used. Since the electrodes lie very close together, there will be room for comparatively little liquid. As invention is claimed: a storage battery having a negative electrode of nickel oxide, a sponge-zinc plate as positive electrode and as electrolyte a solution of potassium or sodium aluminates, which are able to conduct the current, but not to dissolve the sponge-zinc electrodes after discharging.

*Manufacture of Spongy-Lead Plates for Storage Batteries.* H. W. Butler and J. H. May, London, England. Patent No. 715,016, December 2, 1902. Application filed January 2, 1901.

The invention consists in the employment of powdered carbon (preferably charcoal) in the proportion of 10 per cent., mixed with 90 per cent. of lead oxide as paste or active material for storage-battery plates. The mixture in the above proportions is formed into a paste by the addition of dilute sulphuric acid, and pasted in the ordinary manner on the gird or conducting support of the plate. The plate is then placed in a forming solution, which may consist of dilute sulphuric acid only or dilute sulphuric acid containing a salt rich in oxygen, such as sodium nitrate. It is then connected with the positive pole of a source of electricity, a lead sheet being used as cathode, and the current having a density of about 1 ampère for 100 square inches of plate surface, until the carbon has become sufficiently oxidized, this being indicated by gas liberated from the surface of the plate. If sodium nitrate had been added to the electrolyte a new solution of dilute sulphuric acid must then be provided, and a current is passed in the opposite direction, until the active mass is reduced to spongy lead. The inventors are aware that it has been before proposed to use carbon in the form of small particles added to the paste, and their invention is said to consist "in the subsequent removal (either wholly or partially) of the carbon or equivalent by oxidation by electric action, and then the reduction of the porous mass thus formed to spongy lead by reversal of the electric current."

*Accumulator Electrode.* R. A. Katz, Berlin Germany. Patent No. 715,332, December 9, 1902. Application filed August 21, 1899.

This plate is shown in cross section in Fig. 6, and is built up of a non-conducting frame A in the form of a wide-meshed grating, which forms the support for the active material. It can be formed in one piece out of caoutchouc, celluloid or other acid-proof, non-conducting material. Against the frame A rest two thin perforated lead plates C, one on each face, which cover in the active material, and through their many

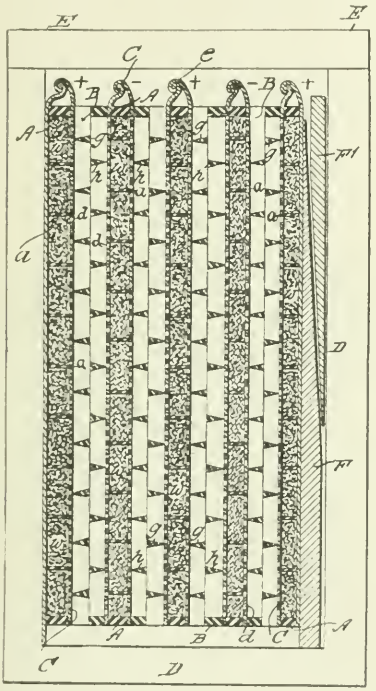


FIG. 6—STORAGE-BATTERY ELECTRODE.

narrow perforations allow access of acid to it. B represents separators, also of non-conducting, acid-proof stiff material, which serve at the same time to afford space for the acid, to keep the positive and the negative plates properly spaced from each other, to press the lead plate against the active material, to assist in supporting the lead plate and, indirectly, also to support the active material. They consist of two superposed gratings *g* and *h*, placed so that the intersections of the one cross the spaces of the other. As advantages are claimed the lightness of the accumulator and the possibility of easily exchanging the lead plates if necessary.

*Accumulator.* F. N. Blanc, Paris, France. Patent No. 715,343, December 9, 1902. Application filed February 17, 1902.

This invention covers a plate made up of a core and frame of aluminium, which are entirely covered with lead. The covering is deposited on the aluminium core by plunging the core, which has previously been provided with a covering of copper by electrolysis, into a bath of molten lead. The covering must be continuous without a break, so as to remove all danger of the attack of the aluminium by the electrolyte. A coating of paste is then applied to both sides of the plate.

*Storage Battery.* L. Paget, New York, N. Y. Patent No. 715,412, December 9, 1902. Application filed September 8, 1899.

The inventor claims that important advantages are secured in storage batteries by the use of a certain silicated material, known as "tufa," as an absorbent material for holding the sulphuric acid or other electrolyte of the battery. He prefers to use a "tufa" obtained from Italy, and has obtained excellent results with "tufa" of probably volcanic origin from the neighborhood of Civita Vecchia. As advantages, he claims the possibility of using an acid of higher specific gravity, a better support for active material of the plates than when "tufa" is not used, and the prevention of fumes in charging a battery, so that a very strong current may be used in charging. He claims that "tufa" remains unchanged, while kieselguhr and pumice stone are liable to break up and form a thin, mud-like material.

*Storage Battery.* L. Paget, New York, N. Y. Patent No. 715,413, December 9, 1902. Application filed August 28, 1901.

This invention "relates to multiple-cell storage batteries—that is, storage batteries formed of two or more cells—the especial object of the invention being to provide a storage battery of large capacity, but of small size and weight in relation to its electrical output. Fig. 7 represents a plan view of such a multiple-cell battery, showing some of the plates in section. A is the cell casing, and is divided into five cells by the insulating partitions B of hard rubber or similar material. The

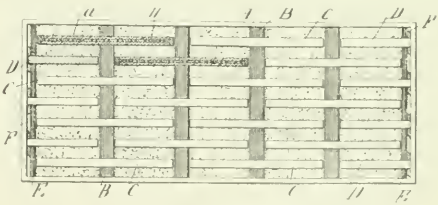


FIG. 7—MULTIPLE CELL BATTERY.

plates are arranged edgewise of the battery and the intermediate electrodes C extend through the partitions B, so that these intermediate electrodes are bipolar electrodes, with the ends of the plates forming the electrodes of opposite polarities. The end electrodes D also extend through insulating plates E at the end of the battery and connect with conducting plates F, provided with lugs for connections. The electrodes are shown as consisting of a supporting non-conducting frame 11, having a perforated web, filled with the active material *a*. Each of the compartments is filled with the electrolyte, which is preferably held or contained by an absorbent material G.

*Storage Battery.* E. J. Knapp, Chicago, Ill. Patent No. 710,056, December 16, 1902. Application filed May 19, 1902.

Buckling in storage batteries usually commences at the corners of the plates, and in order to prevent this triangular corner caps are employed made of substantially-rigid sheet rubber. There is claimed: "A storage-battery plate provided with constraining means at its corner portions for maintaining it in its normal plane against buckling or curling tendencies, the said means being in the form of corner caps."

## GALVANIC CELLS.

*Battery Depolarizer.* C. E. Lockwood and W. C. Banks, New York, N. Y. Patent No. 714,590, November 25, 1902. Application filed September 5, 1900.

The oxide of copper depolarizer used in the ordinary batteries is prepared by oxidizing metallic copper, but as the process of oxidation never goes very deep into the copper, a good deal of it is inactive. The object of this invention has been to avoid the necessity of using this considerable body of useless metallic copper, and the inventors now propose to take

finely divided particles of iron, then plate them with copper and convert the copper into oxide by heating the plated particles in a furnace.

*Gravity Electric Battery.* A. M. Friend, Denver, Colo. Patent No. 715,654. December 9, 1902. Application filed June 8, 1901.

The inventor proposes to overcome various troubles in gravity cells by dividing the cell horizontally into two compartments by a partition adapted to prevent the solid particles of matter from passing from one electrode to the other. The separating risk may consist of pasteboard or other suitable material possessing absorbent or porous property, and is of a size equal to the entire cross-sectional area of the cell.

*Electric Battery.* D. H. Wilson, Chicago, Ill. Patent No. 715,920, December 16, 1902. Application filed April 30, 1902.

The specification describes an improvement in the construction of the zinc carbon cells, by which a greater electrode surface is obtained. The zinc electrode is circular and the carbon electrode is constructed in such a shape that it surrounds, as it were, the zinc electrode on both sides.

MISCELLANEOUS.

*Machine for Washing Matrices Preparatory to Electrotyping.* C. M. Oliver, Baltimore, Md. Patent No. 713,671, November 18, 1902. Application filed August 26, 1902.

The object of the invention is to produce a machine which shall thoroughly and quickly wash away or remove all superfluous particles of black lead or any deleterious substance from the face of the matrix or mold, so that the electrodeposition of the metal on the matrix or mold may be unobstructed and a perfect electrotype copy of the original type-form may be had. For this purpose the inventor puts the molds to be washed face upward on a perforated table, which by means of a suitable mechanism is moved back and forth, while a number of perforated tubes are arranged above it, which spray the mold from all sides as it comes under them.

## CURRENT NOTES.

At the December meeting of the Board of Directors of the American Electrochemical Society, the following applicants were elected to membership: Dr. Leonard Paget, New York; Prof. Dr. Julius Wagner, Leipzig, Germany; R. W. Vicarey, Stafford, England; Prof. Philippe A. Guye, Geneva, Switzerland; Leonard Wilson, Pittsfield, Mass.; Dr. William Dreyfus, New York; Charles J. Pretzfeld, Niagara Falls, N. Y.; August Eimer, New York; Dr. John Shields, London, England; Prof. D. McIntosh, Montreal, Canada; Dr. J. W. Walker, Montreal, Canada; Walter S. Landis, Bethlehem, Pa.; George P. Adamson, Easton, Pa.; Victor Engelhardt, Vienna, Austria; Dr. F. J. Machalske, Long Island City, N. Y.

The American Institute of Electrical Engineers has extended a cordial invitation to the members of the American Electrochemical Society, to attend the Institute meeting on Friday, April 17th; it will be remembered that the annual session of the Electrochemical Society will be held at New York City from April 16th to 18th. At the Institute meeting Mr. Wm. J. Hammer, of New York, will present a paper, illustrated by experiments and exhibits, on the subject of radio-activity and rays in general. Mr. Hammer recently visited Prof. Finsen's Institute at Copenhagen and made an investigation of his treatment of disease by ultra-violet rays; he also investigated the work being done by Prof. and Mrs. Curie at the Curie laboratory in Paris, and some important work that is being done in connection with the properties and applications of selenium. The full title of Mr Hammer's paper is: "Notes on Radium and other Radio-active Substances, and a Consideration of Certain Phosphorescent and Fluorescent Substances;" "The Properties and Applications of Selenium;" "The Treatment of Disease by the Ultra-Violet Rays at the Finsen Institute, Copenhagen."

*Making Steel in the Electric Furnace.*—Just as we are going to press information reaches us that a test of new electric process of making steel has just been made in Lockport, N. Y. Among the gentlemen who are said to have witnessed the test, L. R. Wellman, of Cleveland, and John Fritz, of Bethlehem, are mentioned. The following claim is made: "The process saves 33 per cent. in fuel and nine-tenths in power."

*Susquehanna River Power Plant.*—A newspaper report states that "by the recent formal severance of the street railway system and the electric-light business of Baltimore, the initial step was taken in the $10,000,000 project of developing the water-power of the Susquehanna River and transmitting the same to Baltimore, Philadelphia and Wilmington." The power development of the Susquehanna River is watched with interest also in electrochemical and metallurgical circles.

## CORRESPONDENCE.

### FARADAY'S LAW AND THE THEORY OF ELECTRONS.

*To the Editor of Electrochemical Industry.*

Sir:—The article which appeared under the above title in the November issue of this magazine deserves commendation. Every effort to present in simple form the conclusions of scientific investigation is valuable to scientists in the factory, as well as to those in the university. In the writer's opinion, however, the law of Faraday may be explained in a manner still more simple than that of the article referred to. During recent years, as we are all aware, the general attitude toward the valence theory (better, "hypothesis") has undergone a change. Much as we realize its value to synthetical chemistry, we must admit that in the majority of cases constancy of valence is out of the question, and the reality of bonds is purely hypothetical. It is hoped that the following paragraphs will demonstrate the possibility of understanding Faraday's law without referring to the valence of individual elements and positive and negative bonds.

*Faraday's Law.*—A very satisfactory statement of this law is that made by Professor Nernst: "From the most diverse solutions the same amount of current liberates chemically equivalent amounts of the different ions." The amount of current is measurable, and experience tells us what the ions are; it only remains to determine what are chemically equivalent amounts of the different ions. The unit of comparison of the ions is the hydrogen ion. Any ion which carries the same charge as the hydrogen ion is equivalent to it; its valence is one. An ion carrying double the unit charge has a valence of two, etc. The determination of the number of unit charges carried by an ion (valence of the ion) is particularly simple, because of the close relation between acids, bases and salts, and is readily made clear.

In the solution of an electrolyte, the sums of all the positive and all the negative amounts of electricity must be equal, for the solution acts as electrically neutral. In a solution of hydrochloric acid (an *acid*), the total positive charge of the H ions must be numerically equal to the total negative charge of the Cl ions, and, since the same number of both ions are present, each Cl ion must carry an individual charge equal, but opposite in sign, to that of an H ion. In a sulphuric acid solution, however, the $SO_4$ ion must possess as much negative electricity as *two* H ions positive electricity, for the $SO_4$ ion is in combination with two H ions. In a CuCl solution (*salt*), the Cu ion replaces the H ion of the acid (HCl), and must bear a charge equal to that of an H ion and equal, but opposite, to that of the Cl ion. In a $CuSO_4$ solution, the Cu ion has replaced two H ions; the Cu ion here must carry a charge double that of the H ion. A *base*, e. g., NaOH, is referred to water, the hydroxide of hydrogen; the Na takes the place of

one H of the water, and the Na ion (as well as the OH ion) must carry a unit charge; it is univalent.

In the light of the above, *the number of unit charges carried by an ion is called the valence of that ion, and is equal to the number of hydrogen ions it is in combination with or takes the place of in the given electrolyte.* A gram ion (ionic weight in grams) of a bivalent ion is equivalent to two gram ions of a univalent ion. The same amount of electricity which discharges a gram ion of hydrogen will discharge only half a gram ion of a bivalent ion, or, in general, the ionic weight in grams, divided by the valence of the ion, is equivalent to one gram of hydrogen. Since one coulomb liberates .0104 mg. H, the number of milligrams of any ion liberated by one coulomb is .0104 multiplied by the ionic weight (H = 1) and divided by the ionic valence.

*Theory of Electrons.*—As for this recent theory of Nernst, its connection with the foregoing becomes at once clear when we are told that "electron" amounts to the same as "unit charge," viz.: that which makes an atom or group an ion. The valence of an ion may therefore be expressed in electrons, as well as in unit charges. H. C. COOPER.

Syracuse University.

## Book Reviews.

THE POTASH SALTS: THEIR PRODUCTION AND APPLICATION TO AGRICULTURE, INDUSTRY AND HORTICULTURE. By Dr. Lorentz Albert Groth, with a preface by Samuel Rideal, D.Sc. Lond., F.I.C. London: The Lombard Press, Ltd. 291 pages, illustrated.

This book is devoted to the description of potash salts, the methods by which they are obtained and prepared for the market and their application in the industries.

In the preface Dr. Rideal summarizes the general uses to which potash salts are placed in Great Britain. He calls attention to the pessimistic prophecy of Sir William Crookes in regard to the probable wheat famine of the world, and also calls attention to the renowned experiments carried on at Rothamsted. He finds that the consumption of potash in Ireland is very low, although this potash fertilizer is especially adapted to the potato, which is one of Ireland's chief agricultural products.

In regard to the salts of potash, this book treats of the supply in Canada, and shows that the quantity exported as hardwood ashes is continually decreasing, having amounted to 2,160 barrels in 1804 and only 1,323 barrels in 1808. In France about 2,000 tons of commercial potassium chloride is produced annually by the evaporation of sea water. India furnished about 20,000 tons of nitrate of potash, and about 1,200 tons of potash salts came from the mines at Kalusz in Galicia, the only potash mine in operation outside of Germany.

The historical sketch of the discovery of the natural potash salts is interesting, and shows that as early as 1852 the existence of these minerals was known, but their nature was unknown. The actual working of the mines for commercial purposes began in 1857. There are about 20 mines in all in operation. The dividends paid on the capital shares of the mines are apparently very satisfactory, ranging from 7 per cent., the lowest, to 17 per cent., the highest. The value of the output of the mines for 1902, based upon experience of previous years, is, in round numbers, $8,000,000.

Detailed descriptions of the operations of the mines, with sectional drawings and half-tone portraits of the machinery employed in the mines and in the purification of the salts, are interesting features of the book. A detailed description of all the different characteristics of salt mining is also given. A discussion of the geographical conditions which have made these deposits possible is also an interesting feature of the work. The potash salts are also discussed from a mineralogical point of view, the principal minerals found in the deposits being carnallite, sylvine, kainite, schoenite or pikromerite, polyhalite and kieserite. The different minerals are discussed in detail, both from a mineralogical and chemical point of view. A discussion is also given of the German Potash Syndicate, who practically control the output.

In metric tons, the total output of the mines for 1900 was as follows:

| | Tons |
|---|---|
| Carnallite | 1,607,803 |
| Rock kieserite | 2,047 |
| Sylvinite | 147,791 |
| Kainite | 1,189,394 |
| Total | 3,937,035 |

The amount of carnallite and rock kieserite used directly for agricultural purposes during the past year amounted to 55,489 tons in Germany, and in other countries 2,860 tons. For manufacturing concentrated salts, 1,641,493 tons were used. The amount of kainite and sylvinite used directly for agricultural purposes in Germany was 724,624 tons, and in all other countries 375,007 tons. For manufacturing concentrated salts, 237,554 tons were used, making a total of 1,337,185 tons.

In the potash mines are employed about 7,000 miners, and over 9,000 laborers are employed in the chemical works connected with them. The scientific corps numbers about 300 men. The works are supplied with 642 steam boilers, representing about 66,564 horse-power, and 924 steam engines, representing 59,420 horse-power. Attention is called to the fact that the formation of a syndicate has enormously increased the magnitude of the business and reduced the price of potash to Germans, while outside countries have been compelled to pay abnormally high prices in order to obtain their requirements. The great disadvantage arising out of such a procedure towards foreign agriculture and industry are apparent.

The part of the book devoted to the description of potash salts in industry is fully illustrated, and detailed descriptions are given of the chemical processes by which pure salts are obtained from the crude products. The electrochemical part of the industry is especially well developed. Attention is called to the fact that the history of electrochemistry began with Volta's great discovery, and attention is also called to the prophetic utterance of Davy, in 1806, when he said: "It is not improbable that the electrodecomposition of neutral salts, in different cases, may admit of economical uses." The output of the potash mines of Germany is closely associated with the electrolytic industry applying to salt, magnesium and the alkali and chlorine industry. The application of the electrolytic processes to these industries is briefly described.

From an agricultural point of view, the most important part of the work begins on page 117, with a description of the application of potash salts in agriculture. The consumption of pure potash ($K_2O$) for agricultural purposes is largest in Germany, amounting, in 1900, to 117,712 tons. The United States comes next in the magnitude of consumption, with 65,505 tons. France uses only 8,229, and Great Britain only a little over 7,200 tons. Portugal comes last on the list, with an annual consumption of 43 tons. In amount of potash ($K_2O$) consumed per 100 acres of land under cultivation, the consumption in Germany amounts to 298 pounds; in Holland to 312 pounds; in the United States of America to 42.2 pounds. Thus, while the United States comes next to Germany in the total amount consumed, by reason of the large area under cultivation, the amount per 100 acres consumed in this country is not a very high figure.

Detailed accounts of experiments with potash salts, taken from different authorities, are recorded.

The work is one of great value to the agricultural and technical student by reason of detailed study of the sources and methods of distribution of potash salts and the descriptions of technical processes, and especially on account of the statistics, which are difficult to obtain in the scattered form in which they have heretofore existed. The book will therefore be found useful to the chemist, the engineer and the farmer.

## A NEW ACETYLENE TABLE LAMP.

The excellence of the acetylene light *per se* is so unquestionable that nobody can deny for a moment its enormous commercial possibilities, especially for certain purposes and for certain sections of the country where gas light and electric light are less convenient or entirely out of question. The all important commercial problem for the acetylene lamp manufacturer is at present to convince the general public that acetylene lighting is safe, and that the annoyances and accidents, formerly recorded in connection with the use of acetylene light, are not inherent in the use of acetylene, but were due to the use of inferior apparatus. The whole trouble was that the calcium carbide and acetylene industries developed too rapidly; attracted by the apparent simplicity of the problem, many incompetent inventors designed unsuitable and dangerous apparatus, with the result that the accidents which were due to poor designs and bad construction, were attributed by the public to the use of acetylene itself.

It is very gratifying to state that the conditions of the acetylene industry were very materially improved in recent years by the steady and painstaking work done by the competent engineers of this new industry. The problems involved in the use of acetylene light are now understood, and acetylene lamps are now made in accordance with scientific principles; as a result a steady and healthy growth of the industry is to be recorded. In the following we describe the most recent type of acetylene lamp made by Edward Miller & Co., of Meriden, Conn., for the Electrolite Gas Lamp Co. of New York City, by license under the Beck patents. One of the adjoining illustrations is a sectional cut, showing clearly all details of the design of the lamp; the other sketch shows the lamp separated for filling.

While at first sight of the sectional cut the lamp may look complicated, the operating parts are very few and simple. The lamp consists of three chambers, namely, a water chamber below, a carbide chamber above, and a movable gas holder which operates to bring the carbide into the water. The movable gas holder consists of a rubber bag and is fastened on the top wall of the carbide chamber. To this movable holder is fastened rigidly a feed stem which moves with the top wall of the gas holder and opens the feed when the gas holder is nearly empty and shuts off the feed when it is filled with gas.

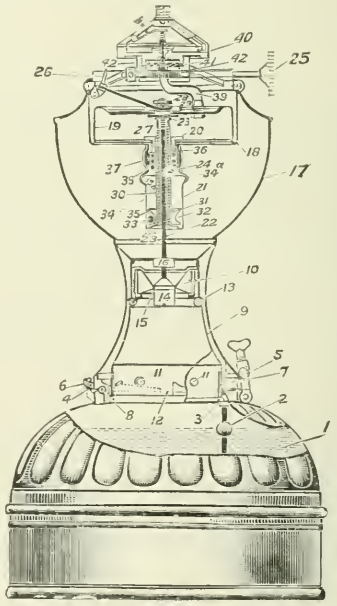
The gas in the lamp varies in pressure. Immediately before carbide is fed the pressure is less and as the carbide falls the pressure is raised slightly by the additional gas generated. The regulator or governor on the top of the lamp on to which the burner is fastened is an auxiliary means for keeping the flame uniform. It has absolutely nothing to do with the generation of gas. In the carbide chamber is located an auxiliary device named the "safety lock," which also has nothing to do with the operating of the lamp. Its function is to prevent further feeding when the lamp is tipped over so that the water cannot enter into the carbide chamber. It automatically arrests the further movement of the feed valve when the lamp is on its side, but permits the free movement thereof when the lamp is upright.

The gas after it is generated passes through the same opening through which the carbide falls and is dried by passing through the carbide and then screened by the felt filter. The mechanism in the top of the lamp over the gas bag is for the purpose of manually arresting the feed. When spindle 25 is turned inward the feed is positively shut off.

All the details of construction may be clearly seen from the sectional cut; 1 is the water fount. The round button 2 shows the height to which the water is filled; 3 is the joint ring on the fount; 4 is the loop into which hook 6 is passed for fastening the top to bottom of lamp; 5 is a clamp and screw which is thrown inward or outward in fastening or unfastening the top from the bottom part; 7 is the joint ring on the top part of the lamp which has cemented to it the round gasket 8; 9 is the stopper which carries the rubber feed valve 10. The stopper 9 has two lugs or projections 11, which are inserted into the slots 12, and is twisted to the left before taking it out or to the right after inserting it. The rubber valve 10 need not be removed at any time except when it is renewed.

The small gasket ring 13 on the stopper prevents the water running into the carbide when the lamp is tipped over; 14 is the metal feed valve which works up and down to close and open the carbide port 15; 16 is the auxiliary stop which registers in port 15 when the lamp is empty.

17 is the carbide holder; 18 is the top wall of the carbide holder which forms a receptacle for the flexible rubber gas holder or bag 19. The bag 19 is permanently secured to the lower side of 18 by means of the threaded nipple 20; 21 is the safety lock and filter combined and is located in the carbide chamber; 22 is the feed stem carrying metal valve 14 and auxiliary stop 16; 23 is the upper spring sleeve and is screwed on the top of feed stem 22; 23*a* is the lower spring sleeve.




CROSS SECTION OF LAMP.

24 is the feed spring which forces the gas out of the holder 19 into the burner. When carbide falls in the water, the gas inflates the holder 19 and expands spring 24, and as the gas passes out of the burner the spring contracts, deflates the holder 19, and forces feed stem 22 downward until an opening is made and carbide falls into the water. The gas so generated reinflates the holder 19 and the operation is repeated automatically until the carbide runs out or until the feed stem is forced upward by screwing in spindle 25.

26 is a bell crank lever pivoted at the side in the bag chamber and in engagement with the top of the bag. The feed stem 22 is screwed into nipple 27 and fastened with a lock nut 28. Nipple 27 is fastened in the top wall of bag by means of nut 29. Under this nut 29, lugs are placed with which the bell crank lever 26 engages.

30 indicates a sleeve which covers the feed spring 24 and is part of safety lock. The upper end of sleeve 30 is secured to the feed stem 22 between spring sleeve 23 and bag nipple 27, so that it has to move with the feed stem and the top wall of holder 19. On the lower end of this safety lock sleeve

is fastened a round metal part 31 with groove 32. In this groove rests a steel ball 33. Around this feed mechanism and safety lock is a casing 34, forming a cage for the ball 33. Immediately above the lower part of this casing 34 is an annular enlarged channel 34*a*. If for any reason the lamp is on its side and in operation, the feed mechanism will continue to move until the opening is made in the carbide port 15, but instead of the carbide falling by reason of the position of the lamp, water will run into port 15 and attack the carbide. Gas will instantly be generated and the holder 19 be inflated to its full capacity, and as the feed mechanism and that part of the safety lock carrying ball 33 are fastened to the top wall of bag 19, part 31, carrying ball 33, will be taken upward to a point parallel with part 34*a*, and the ball 33 will fall from the groove 32, into the annular channel 34*a*. As soon as the gas has burned out to permit the spring to contract the top of the bag, the feed stem and safety lock device will move downward again, but as the ball 33 has fallen into the channel 34*a*, and projects into the path of part 31, the upper part of 31 indicated by 35, will strike against the ball and wedge it between 35 and the edge of channel 34*a*, indicated by 35*a*, and prevent the further opening of the feed port 15. The gas remaining will pass out and burn and the flame go out.

36 is the upper part of casing 34 which carries the felt filter 37, through which the gas has to pass on its way to the holder 19. In this casing are holes 38, which admit the gas. This casing 34 serves: first, to hold the bag 19 in place; second, as a filter; third, as a safety lock, and fourth, as a guide and holder for the feed device; 39 is a flexible tube through which the gas passes from the bag or holder 19 on its way to the burner; 40 is the regulator or reducing valve which serves to give a uniform burning pressure. Below this regulator is another filter 41 in box 42. Box 42 also serves as a support for the shut-off spindle 25. By removing the top perforated cap of the lamp when burning, the operation of the bag 19, bell crank 26, and shut-off screw may be seen.

LAMP SEPARATED FOR FILLING.

The second sketch shows how the lamp is separated for filling. The shade is removed; the top is separated from the bottom part of the lamp and the top part is set upside down on the shade ring, as shown in the figure. The stopper is then removed from the top part, carbide is poured in and the stopper is replaced. The residue is then poured out from the lower fount, and the fount is washed both inside and outside; fresh water is then filled in. The residue is a good fertilizer or disinfectant for toilets.

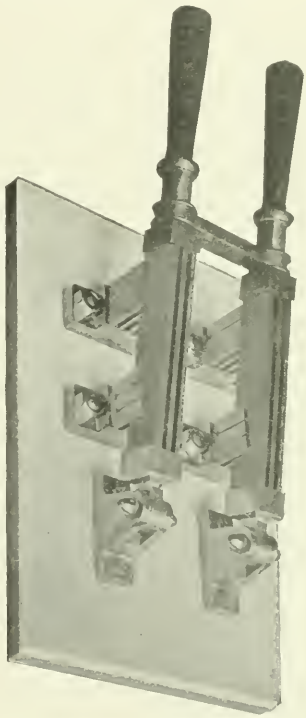
The lamp has been accepted by the consulting engineers of the National Board of Fire Underwriters, and is included in the list of permited acetylene devices issued by them.

## 1,500 AMPÉRE SWITCH.

Electrochemical work is essentially large current work and, therefore, apparatus and appliances for electrochemical plants must be designed just with this point in view.

The adjoining diagram shows the standard Eyanson switch for 1,500 ampères, as made by George T. Eyanson & Co. in Philadelphia, for use in electrochemical plants. All switches, made by this firm for 800 ampères and over, are made up of multiple blades, to insure ample contact surface and ventilation of the parts.

The blades and clips used give a large capacity switch in a comparatively small area. The switch is rated at 1,000 ampères



1,500 AMPERE SWITCH.

per square inch of cross section, and 50 ampères per square inch of contact surface. The blades and dips are of cold rolled copper and all other current carrying parts of cast copper.

## POROUS DIAPHRAGMS.

Porous diaphragms are of very great importance for many electrolytic processes in which the anodic and cathodic portions of the electrolyte are to be kept separate. The quality of the porous diaphragm very often determines the degree to which a certain electrolytic process is successful. In recent years the well-known firm of Villeroy & Boch, in Mettlach, Germany, have made extended researches with a view of finding the best conditions of making a porous diaphragm for use in acid solutions, which shall have at the same time a low electric resistance, a small mechanical permeability, and a long life. From the results of tests made by Dr. Max LeBlanc, and extending over a long time, it appears that the manufacturers have successfully solved this problem. Dr. LeBlanc used these diaphragms in a process of electrically reoxidizing the reduced chromic acid resulting from its use as an oxidizing agent in many industries. Some details given by him in the behavior of these diaphragms are of great interest.

Two different compositions were tried. The older composition was 75 per cent. of $SiO_2$ and 25 per cent. $Al_2O_3$. In the newer type about 2 per cent. of the $Al_2O$ is replaced by alkali. The newer plates are superior to the older ones, in so far as they have a smaller electrical resistance (this means, of course, that the resistance of the electrolyte in the dia-

phragm is matter, as the diaphragm itself acts as an insulator. With a current density of 300 ampère per square centimeter a plate of 5 mm. (or 1.5 inch) thickness showed a drop of potential of 0.4 volt with the older chemical composition, and a drop of only 0.17 volt with the newer composition.

The plates have a different mechanical permeability according to the size of the pores. Diffusion is much smaller through plates with very fine pores than through plates with larger pores. An interesting conclusion reached by Dr. LeBlanc is that it is possible to make a diaphragm which has at the same time a very low electrical resistance and a very small mechanical permeability. In the latest type of diaphragm the pores are so small that they cannot be seen with the bare eye. The diaphragms are claimed to be thoroughly acid-proof and to last practically an infinite time in acid solutions; they are, however, not suited for alkaline solutions.

Messrs. Villeroy & Boch make such porous diaphragms up to the following maximum sizes: rectangular plates 23⅝ inches x 15 inches; square plates 23⅝ inches x 23⅝ inches; cylinders of 27½ inches height and 11⅞ inches diameter; boxes, 29½ inches by 29½ inches by 4 inches.

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## DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

*Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.*

*This digest of electrochemical United States patents prior to July, 1902, will be one by classes, setting out for comparison in each class those devices which have the same object, or those methods which seek the same results. In each class the patents will be arranged chronologically. The digest will be complete in the sense of covering every point which is touched upon in the original specification.*

CAUSTIC ALKALI AND CHLORINE PROCESSES *(Continued).*

508,241. James C. Richardson, London, England, November 17, 1893.

Narrow, rectangular cathode bells, with flared lower ends. Bells open at the upper end, and provided with side outlets for caustic. Cathodes, horizontal grids of copper strips in the flared lower ends of the bells. Anodes, horizontal carbon rods, extending from lead plugs seated in the side wall of cell and serving as terminals.

508,804. Henry S. Blackmore, Mount Vernon, N. Y., November 14, 1893.

Apparatus consists of three rectangular vessels, arranged in a row and connected by siphons. Each siphon is a flat tube, of the width of the vessel, and has an exhaust pipe connected to its bend and a valve at one end. Intermediate vessel contains brine; end vessels, water only. Anode and cathode, perforated, inclined plates in the end vessels, respectively. Perforated salt reservoir depends into middle vessel, and has a steam coil within it. Device for maintaining a constant level in each vessel, and outlets for electrolytic products from end vessels.

510,834. Henry S. Blackmore, Mount Vernon, N. Y., December 12, 1893.

Cell divided by parallel vertical diaphragms into three compartments. Electrolyte fed into one end of middle compartment, any overflow escaping at the other end. End compartments contain water only, and have constant level devices and outlets for electrolytic products. Anode and cathode, serrated, vertical plates in end compartments, respectively. Hydrometer in cathode compartment to show level of caustic. Maintains water level in end compartments slightly above brine level to hinder passage of brine through diaphragms.

510,900. Elisha B. Cutten, New York, N. Y., December 19, 1893.

Iron vessel, serving as cathode, closed at top by an earthenware bell, with water-seamed inlet for brine and exhaust pipe for chlorine. Cathode, a series of vertical carbon bars, supported on an earthenware disc and having carbon pins extending through the disc into a mass of insulation. Insulated wires extend from terminal out through side of vessel. Cathode support rests on a disc of wire gauze, which permits caustic accumulating in bottom of cell, to be drawn off through a central discharge pipe.

511,682. Antoine J. O. Chalandre, Paris, France, December 26, 1893.

Anode compartment, a rectangular box built of non-conducting plates, with rubber packing. A number of inclined porous tubes, arranged in vertical rows, pass through opposite sides of the box. Vertical carbon anodes between the rows of tubes. Cathodes, a series of vertical sheet-iron combs, the teeth of which extend into the tubes. Hood for collecting hydrogen covering higher ends of tubes. Brine circulates between anode compartment and a separate saturating vessel.

512,266. Emile Andreoli, London, England, January 9, 1894.

Rectangular iron vessel, serving as a principal cathode. Supplemental cathode, also a rectangular box, of porous carbon, one or more layers of fine wire gauze, or two layers of wire gauze, with an intermediate space filled with crushed coke or iron filings, arranged within the outer vessel. Anodes of carbon or a basket of platinum gauze. Modification, with slate vessel containing vertical metal-plate cathodes and supplemental porous catnodes. The supplemental cathodes are connected to the principal cathodes by a fine wire, the resistance of which is calculated to shunt the desired current. Made electrolyze sulphates, nitrates, etc.

514,318. Greenwood Division of 489,677.

Cathode, a body of carbon having a cavity or space, the surface of which is electroplated with copper. A copper rod or plate conductor is soldered to the copper deposit.

514,681. Ernest A. Le Sueur, Ottawa, Canada, February 13, 1894.

Stoneware cover of the cell has a cam-ring support for anode. Rotation of the ring adjusts vertical height of anode. The upper surface of cam ribs is also inclined transversely, so that the anode can be tilted to immerse all parts equally in the brine.

518,040. Ernest A. Le Sueur, Ottawa, Canada, April 10, 1894.

Double diaphragm, consisting of spaced sheets of asbestos clamped against opposite faces of a lead frame by non-conducting side frames. Intermediate space filled with brine, maintained at a higher level than in anode and cathode compartments, or with a liquid of greater specific gravity than that in said compartments, thus preventing percolation of anode and cathode solutions into the diaphragm. The entire supply of brine may be fed into the diaphragm, and through it to the cell compartments.

518,785. Ernest A. Le Sueur, Ottawa, Canada, April 24, 1894.

Similar to 518,040. Anode side of diaphragm, a sheet of abestos or porous clay; cathode side, a sheet of parchment, bichromated gelatine or thick cloth, against which is clamped the cathode, of iron netting. May subdivide diaphragm space by a second sheet of asbestos.

520,257. Thomas Craney, Bay City, Mich., May 22, 1894.

Iron containing vessel, connected as cathode. Anode vessel, with curved bottom, of asbestos, cotton or sand, supported by a sheet of cotton cloth on a net and frame-work of iron, in electrical contact with the iron vessel. Anode, a layer of broken gas carbon resting on the asbestos, current being fed to it through a number of perforated clay tubes filled with carbon. Circulation of brine through anode chamber, and of water through cathode chamber. Several cells may be connected by pipes with rubber sections, enabling caustic to flow from cell to cell, or any cell to be cut out for repair. Exhausts chlorine by a fan.

[*To be continued.*]

# Electrochemical Industry

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## Electrochemical Industry

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## ELECTROPLATING.

In this issue we print several articles on the practice and theory of electroplating, which we trust may prove interesting to the practical electroplater, as well as to the electrochemical scientist. With the only exception of the battery industry, electroplating is the oldest electrochemical industry; it also is a large industry, there being more than 1,100 electroplating firms in the United States alone, and the products of this industry are in general use. This industry, however, has developed as a separate industry, touched but faintly by the development of other electrochemical industries, and practically unaffected by the progress of electrochemical science. In the electroplating industry, the rule of thumb has been reigning supreme for many years, although recently signs of improvement and healthful progress are plainly evident. But the improvement is due to the introduction of improved apparatus rather than to a better understanding of the principles of electroplating.

The methods and apparatus formerly used by electroplaters were extremely rude. Mr. H. L. Haas, in an article published in this issue, sketches in an amusing manner the method by which in former years an electroplating solution was generally made up by the workingman who had to attend to it. It is a great advance that electroplaters now appreciate the importance of weighing the various materials which they put into the solution. They now understand that to get good results they must exactly know the composition of the solution when they start the operation. Another advance of equal importance is that the electroplater now also recognizes the necessity of carefully producing and maintaining the electrical conditions required to get the desired result. The old-time plater's voltmeter was an old rusty file which they used to put across the two wires, making the connection and getting a spark, since they knew the electric current was flowing, but that was all they knew. In recent years exact measuring instruments are being largely introduced in electroplating establishments, complete switchboards with instruments and rheostats are in the market specially designed for the convenience of the plater. The design of electroplating dynamos was also materially improved. The result is that the electroplater is now in a position of knowing exactly the conditions of his operation by weighing the materials and following exactly the instructions regarding the arrangement of the plant and the regulation of voltage and current, a careful attendant will get good deposits even though he may not know anything about the principles of electrolytic action. This is surely a great practical advance and accounts for the improved results obtained in recent years. But while it would be folly not to appreciate the great practical importance of this progress, yet it is necessary to emphasize that a more important advance must still be made: that is all of us have still much to learn concerning the fundamental principles underlying this subject.

It is certainly a good thing to know exactly the conditions under which a good adhesive deposit is obtained, and to know that by changing the conditions the deposit changes in a certain way. Such knowledge is the result of careful observations and long practical experience. But to apply such knowledge to other different cases, it is necessary to know *why* the deposit is good under certain conditions and poor under others; *i. e.*, it is necessary to understand the general theoretical principles underlying the electrolytic deposition of metals. It is but fair to confess our ignorance of these principles in many respects. Future progress depends upon the co-operation of the practical electroplater and the theoretical scientist; in order to promote such co-operation, we publish the articles on electroplating in this issue, and we hope that they may interest both practical men and scientists in the fascinating problems involved in electroplating. A better understanding of these problems is sure to bring about fruitful results for theory, as well as practice.

At first sight, when viewed from a theoretical point of view, the process of electroplating seems to be one of the simplest cases of electrochemical action, but when studied more accurately it is found to be very complicated. The chemical nature of the electrolyte, the chemical nature of the metal to be deposited, and that of the metal upon which the deposit is to be made, the concentration of the electrolyte the current density and the temperature, all are found to be important factors influencing the properties of the deposit obtained. We know that distinct relations exist between these factors and the properties of the deposit obtained, but we understand these relations only in part. Various interesting observations, mentioned in the articles on the following pages, illustrate this point very clearly.

That the chemical nature of the electrolyte is of the utmost importance, was long known among electroplaters; in fact the patent literature of electroplating is practically a long series of recipes for plating solutions. We know that in many cases certain additions are of great advantage, but we are still more or less in the dark why it is so. For instance, Prof. C. F. Burgess and Mr. Carl Hambuechen, in their article in this issue, mention that a small quantity of carbon bi-sulphide in a silver-plating solution enables a polished coating to be obtained, whereas when omitted the surface would become rough much more quickly. These authors point out that viscosity and surface tension of a solution seem to have some relation to the quality of the deposit; if a substance is added to a metal salt which alters these properties, the quality of the deposit may be influenced. The same authors point out that the quality of the deposit depends upon the degree to which the plating solution wets the surface of the cathode. It is quite evident that to get a good deposit, the solution should thoroughly wet the entire surface; hence, as this property can be imparted by additions of other soluble substances, their addition will improve the deposit. The same authors mention a very peculiar experimental fact: the kind of deposit which was obtained from a zinc sulphate solution prepared by dissolving crystals of zinc sulphate in water was found to be materially different from the deposit obtained under similar conditions of temperature, current density and contents of solution, in which case, however, the solution was prepared by dissolving pure zinc in dilute sulphuric acid until it became of the same neutrality as the solution obtained by dissolving the crystals.

Mr. Woolsey McA. Johnson discusses the same problem—the influence of the chemical nature of the solution—from the point of view of the electrolytic dissociation theory. He calls attention to the fact that double salts are found to give good results in practice, and he advances the view that these good results are due to two different causes: to the increased cathode-potential, and to the fact that the double salt always furnishes the catholyte with a good supply of cations by its continuous decomposition. It will be seen that the influence which the chemical nature of the solution has upon the quality of the deposit, may be considered from very different points of view, and it is quite probable that when this matter will be better understood in future, it will be found that here a great many different influences are playing a role.

The influence of the chemical nature of the metal to be deposited and of the metal upon which the deposit is to be made, is discussed in an interesting article by Dr. Louis Kahlenberg. He points out that the alloying power of the electrolytic deposit with the coated metal underneath is a factor determining not only the strength with which the deposit adheres, but also the length of time the plated article will wear and resist corrosion. There is a tendency of the two metals to dissolve in each other, a tendency of mutual interpenetration of their masses. The stronger the affinity of the metals for each other is, the better the deposit is apt to adhere; a clean, slightly roughened (etched or scratch-brushed) surface facilitates alloying. The practical conclusion reached by Dr. Kahlenberg is to plate those metals or alloys upon each other that possess sufficient affinity to coalesce well, and yet will, at the temperature at which the plated objects are to be kept, diffuse but very slowly into each other.

Prof. Burgess and Mr. Hambuechen discuss the same subject, but think that the alloying phenomenon cannot be held as a universal one. They assume that in some cases no formation of an alloy takes place, but direct cohesion, which is established when solid particles are brought into intimate contact. However that may be, it is certain that what is needed, is intimate contact between the molecular particles of the one metal with those of the other metal—not branches, twigs and outgrowths, but rather roots and a dense undergrowth.

## PATENTS AS LITERATURE.

The United States has issued, to date, upward of 700,000 patents, each of which presumably embodies an original idea, of which the individual patent is a full and adequate expression. These patents are classified according to the several arts, and the vast mass of material so collected constitutes a rich field for study and investigation.

This patent literature, however, does not consist in general of a series of accurate and conservative monographs; it is rather, for the most part, in the form of more or less fragmentary notes written by the inventor, or, at least, from the inventor's viewpoint, and expressing not so much the accomplishment of a result as the formulation of a hope.

Of course, there are exceptions—descriptions so clear and convincing that the patent specification is what the law intended that it should be, a clear expression and definition of the patentee's contribution to progress. Too often, however, the description is a recital of imaginary defects of the devices of the prior art and illusory advantages of the new construction. In such cases an effort to attain any clear idea of the practice of the day or of the development of a given principle, through a study of the patents alone, will be futile.

This is unfortunate, but in large part it is irremediable. The average inventor is often characterized as visionary, which is true in part only. More accurately, his dominant characteristic is hopefulness, and no law exacting accuracy will ever prevent him from painting his thought with the bright colors which, to him, are real. To read patents with profit, one must understand this and sympathize with it; one must see with the inventor's eyes in order to understand his thought. Then whatever of value or suggestiveness the idea may contain will become clear.

## ON ENTROPY.

A very animated and amusing war on entropy is raging at present in our British electrical contemporaries. In a note in his recent presidential address to the (British) Institution of Electrical Engineers, Mr. James Swinburne claimed that nearly all text-books are wrong in defining entropy. This remark elicited a sharp answer by Past President Prof. John Perry, which was followed by others, and the war is still going on merrily. If it was simply a quarrel on technical terms, a new case of the tower of Babel, there would be no use in saying much about it; we could simply mention that Mr. Swinburne claims to base his views directly upon Clausius, who coined the term and established the second principle of thermodynamics; and that, according to Professor Perry, it is a matter perfectly well known that Clausius used a term in one sense and all modern men use the same term in another sense (the term "all modern men" being again open to discussion); and that Lord Kelvin says entropy is Clausius' word, and persons concerned in it will find its definition in Clausius' own writings.

However, it is not simply a quarrel about words. If we understand Mr. Swinburne correctly, he wants to protest against the predominant place which is given to reversible processes in the discussion of the second principle of thermodynamics in ordinary engineering text-books. He wants to emphasize that reversible processes are only an ideal case, never fulfilled in practice, and that, in fact, the cardinal point of the second principle of thermodynamics is that in nature we always have irreversible processes, in which the entropy always increases. And in this respect Mr. Swinburne is right, without doubt. The well known integral representing the heat supplied from an outside reservoir to the system under consideration, divided by the absolute temperature at which this heat exchange takes place at any moment, serves only as a method of determining the value of the entropy, and it is here an essential supposition that the process by which the system is brought from one condition to another is absolutely reversible. Thus the reversible processes serve only for determining the value of the entropy, but in nature we have only irreversible processes.

The difficulty in the whole matter seems to arise from the fact that the value of entropy is found by determining the value of the integral mentioned above for a reversible process. Being thus mathematically defined, its physical meaning is obscure. We here arrive at a limit of our knowledge. We can give the value of entropy, independently of that integral, only for gases and dilute solutions, but in all other cases we must go back to that integral. Nevertheless, we should take pains to connect a physical meaning with the word entropy. If we do this many misunderstandings will disappear, and especially the fundamental difference which exists between the principle of the conservation of energy and the principle of the increase of entropy will become evident; that is, the difference between the first and second principles of thermodynamics. It is still too often thought that the second principle of thermodynamics is only an appendix to the principle of the conservation of energy, while, in fact, it states something with which the energy principle is not at all concerned.

If an isolated system is given which passes from one condition into another, the first principle of thermodynamics states that the energy of the system in one condition is exactly the same as in the other. Viewed from the principle of the conservation of energy, there is no preference for either condition; both are equivalent, and in both the system has the same energy. But we know that a change will always take place in a certain direction, and not in the opposite direction. The energy principle does not indicate in any way what this direction is, but the second principle of thermodynamics does. This is indeed the fundamental point of this principle. We can accordingly give a popular definition of entropy, which we believe is due to Planck. It is that the entropy of a system is the function representing the preference which nature gives to one condition of the system above another condition. Entropy will therefore always increase. To mention one instance, if we have two solutions of the same electrolyte, but of different concentrations, this system of the two solutions has a certain entropy. When the two solutions diffuse, the entropy increases, because this is an irreversible process. Hence the process will always take place in such a direction that the dilute solution becomes more concentrated, and the concentrated solution more dilute. This enables us, for instance, to always predict the direction of the e. m. f. in a concentration cell, and it is absolutely wrong to assume that it is of any influence whether the heat of dilution is positive or negative. It is true Berthelot believed that the direction of a chemical process is determined by the amount of heat which the action can evolve; the reason why hydrogen and oxygen combine and form water, and why not the reverse takes place, is, according to Berthelot, that the former process evolves heat. True, this view has been predominant in thermochemistry for many years. But we know now that Berthelot's principle is wrong as a general principle, and in its place we have the second principle of thermodynamics: a chemical process takes place in such a direction that the entropy increases. We hope to return to this point in connection with some special electrochemical subjects in future issues.

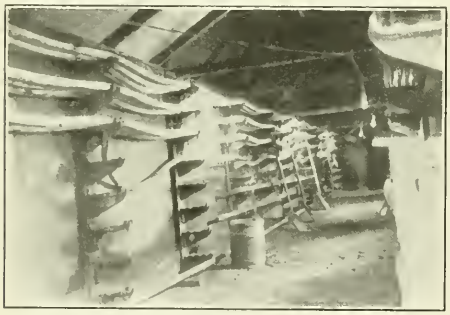
## NIAGARA POWER PLANT COMPLETELY SHUT DOWN BY FIRE.

By Frank C. Perkins.

The thunder shower of Thursday, January 29th, damaged the 75,000 horse-power Niagara Falls power plant to such an extent that it was necessary to stop every one of the fifteen 5,000 horse-power alternating-current generators. All of the current from the 50,000 horse-power plant in power house No. 1 passes through the cable bridge, carrying the current from the power house to the step-up static transformers in the transformer house across the canal. The temporary connections of the new power house No. 2 were also of such a nature that the fire which occurred in the cable bridge and transformer house made it impossible to utilize these machines.

It is believed that a stroke of lightning formed a serious short circuit in a 2,200-volt local circuit in the cable bridge, and the roof of the bridge, which was of wood, took fire, as well as that of the transformer house, resulting in the destruction of every high-tension lead-covered cable between the power house and the transformer, shutting down the entire plant.

In extinguishing the fire large quantities of water were poured into the transformer house, badly damaging the air-cooled transformers, which were located near the entrance to the cable bridge. It is thought that little damage was done to



CABLE BRIDGE ON THE MORNING AFTER THE FIRE.

the oil-cooled transformers by the fire, and the air-cooled transformers may be serviceable as soon as thoroughly dried out.

The accident happened about midnight, and the quick work of Superintendent Philip P. Barton and his men resulted in the replacing of 36 of the cables before morning and the replacing of a temporary roof on both bridge and transformer house, and four 5,000 horse-power machines were in operation.

Of the total 75,000 horse-power generated in the two power houses, about one-third is transmitted over the 22,000-volt lines to Buffalo for operating the street railways and lights of the city, as well as furnishing power to many of the newspaper establishments and various factories. The storage-battery plants of the International Railway Co. and the Buffalo General Electric Co. were of service for several hours, and the large reserve steam plant of the railway company was soon placed in operation and the car lines were never all shut down.

The arc and incandescent-lighting service of Buffalo and Tonawanda was not so fortunate, and both cities were without light until Thursday evening.

The power plant of the Niagara Falls Hydraulic and Mfg. Co., which obtains its power from a surface canal through the city of Niagara Falls, was able to render great assistance during the trouble, and the lights of that city were kept in operation, as well as the street railway service.

It is stated that the damages will probably exceed $50,000, and undoubtedly as much again if the losses of the tenants and other power users is considered. The construction of the bridge and transformer house is entirely of iron and stone, except the roofing, which is of wood. And while the fire itself caused little or no damage to the transformer plant, the water, of course, put the transformers of the air-cooled type entirely out of service for the time being. Had tile or other fire-proof roofing been used, undoubtedly the damage would have been much less, and might have saved the plant from being entirely closed down. A second conductor bridge, with duplicate cables, would unquestionably have rendered the accident less serious, as "all of the eggs would not have been in one basket," and the current might have been sent to the transformer house through the second set of conductors.

It may also be considered doubtful whether it is wise to place all of the transformers of a 50,000 horse-power plant in a single building, as the burning out of one or more may affect a number of others. This disastrous fire at the Niagara Falls plant shows how much care is necessary in the protection against lightning and the desirability of using fire-proof materials in every portion of a modern electric power plant.

The duplicating of transmission lines is now extensively practiced, and is undoubtedly advisable. And there is little question but that the engineers of the five new plants being constructed on both sides of Niagara River, above and below the falls, will carefully consider the causes of this serious shut-down in all its phases, and endeavor to make such provisions that a similar accident will be impossible.

The engineers of the Niagara Falls power plant are to be congratulated on the rapidity with which they were able to place their power lines in service again after so serious an accident. This is, however, characteristic of electrical engineers in both lighting and power plants. They usually are equal to almost every emergency, no matter how serious it may be. The accompanying illustration shows the interior of the cable bridge the morning after the fire, with new cables in place and roofing completed.

## PROPOSED (BRITISH) SOCIETY OF ELECTRO-CHEMISTS AND METALLURGISTS.

At a meeting of the Provisional Committee of the proposed (British) Society of Electrochemists (see Electrochemical Industry, Vol. I, page 4, Sept., 1902), held on January 6th, Mr. James Swinburne in the chair, it was resolved, in consideration of the support and encouragement received in response to circulars recently issued, to hold, on February 4th, a general meeting of the supporters of the movement and formally inaugurate the work of the Society and elect a president and council.

It has been suggested that there should be two classes of members—members and associated members—the subscription fees being two guineas and one guinea respectively (*i. e.*, about $10 and $5).

The honorable secretary of the Provisional Committee is F. S. Spiers, 82 Victoria street, London.

The following gentlemen have consented to be nominated as members of council of the proposed society: President, J. W. Swan, F.R.S.; vice-presidents, Prof. A. Crum-Brown, M.D., D.Sc., F.R.S., Sir Oliver J. Lodge, D.Sc., F.R.S., Dr. Ludwig Mond, Ph.D., F.R.S., Lord Rayleigh, D.C.L., F.R.S., Mr. Alexander Siemens and Mr. J. Swinburne; council, Messrs. George Beilby, Bertram Blount, W. R. Cooper, M.A., B.Sc., Sherard Cowper-Coles, A. G. Charlton, F. G. Donnan, M.A., Ph.D., Prof. A. K. Huntington, F. Mollwo Perkin, Ph.D., W. S. Squire, Ph.D., and O. J. Steinhart, Ph.D.

Statistics of Electroplaters. Census Bulletin No. 150, issued September 15, 1902, gives the number of electroplating firms in the United States in 1880 as 221, and in 1900 as 422, the value of their products being given as $1,975,700 and $3,007,455 respectively. The number of "galvanizing" firms in 1900 is given as 28, and the value of their products as $2,470,703. It seems that these figures are too low, for, according to reliable private information, there are more than 1,000 electroplating firms in the United States.

## THE ALLOYING OF METALS AS A FACTOR IN ELECTROPLATING.

BY PROF. LOUIS KAHLENBERG, PH.D.

At the meeting of the American Electrochemical Society, at Niagara Falls, Professor Haber demonstrated experimentally that when an aqueous solution of a salt of sodium or potassium is electrolyzed, using a cathode of tin or lead, hydrogen is formed, and a dark cloud, consisting of the finely-divided heavy metal, envelops the cathode. With a lesser current density, the cloud does not form, the surface of the heavy metal being simply roughened. It was pointed out by Professor Haber that here the alkali metal actually is deposited on the cathode, forming an alloy with the latter, which is then decomposed by water, yielding hydrogen secondarily and the finely-divided metal. This experiment is of great value in settling the mooted question of whether the hydrogen liberated at the cathode during the process of electrolysis of an aqueous solution of a salt of an alkali metal is of primary or secondary origin. While, as Professor Haber stated in the conclusion of his paper, the experiment is perhaps of more theoretical than practical interest, nevertheless it is simply a striking illustration of a general fundamental principle that underlies all electrolytic deposition of metals.

When one metal is deposited electrolytically upon another, the process of alloying always goes on to a greater or less extent, which is determined primarily by the nature of the metals, and secondarily by the conditions of experiment. Among the latter are of special importance the original condition of the surface of the cathode, nature and concentration of the electrolyte, temperature, potential and current density. These all have been well recognized and thoroughly discussed in text-books as important factors in securing desirable, dense, well-adhering deposits that will admit of being polished and burnished. The important fact that the alloying power of the electrolytic deposit with the coated metal underneath is a factor determining not only the strength with which the deposit adheres, but also the length of time the plated article will wear and resist corrosion, has not been sufficiently recognized.

The alloying power of two metals consists of a specific attraction of the metals for each other, a tendency to dissolve in each other, or, as it is put by others, a tendency that the metals have to bring about a mutual interpenetration of their masses. This force is no doubt chemical in character, slight though the affinity may be in some cases. The alloys of mercury, the amalgams, especially those of the alkali metals, have become of considerable importance in the electrolytic preparation of caustic alkalies and of alkali metals. Here the alloying of the alkali metal with the mercury constituting the cathode is well recognized. But when gold is plated on lead, for example, an alloy of gold and lead is just as truly formed at the point of contact between the two metals. A thin plating of gold on lead will gradually soak into the lead entirely as the alloying process continues. This goes on at room temperatures. The experiments that Roberts Austen made in 1900 ("Proceedings of the Royal Society," London 67, 101-5) demonstrating how gold diffuses into lead at ordinary temperatures are of special interest in this connection. A thin plating of gold on zinc is absorbed in a few days. The "tarnish" becomes visible very soon. After the deposit has been absorbed, the gold may be exposed again by carefully etching away the zinc from the surface by use of a dilute acid. The experiment of Gore, illustrating how copper plated on platinum penetrates into the latter, is well known to electroplaters.

This affinity between metals asserts itself the moment one metal is deposited on the other. The stronger the affinity of the metals for each other is, the better the deposit is apt to adhere. On the other hand, the plating is also more apt to be absorbed by the base metal underneath the greater the tendency of the metals to alloy is. A higher temperature generally aids this alloying process, and so it is that frequently much better adhering deposits are obtained by working at temperatures above the ordinary. A clean, slightly roughened (etched or scratch-brushed) surface of the cathode clearly facilitates the alloying of the deposit with the metal of the cathode, for thus a more intimate contact is secured. When two metals are to be alloyed under ordinary conditions, the affinity between them must overcome their cohesions. This frequently requires a high temperature. In the process of plating the affinity between the metals clearly does not initially have to overcome the cohesion of the deposited metal, since the latter is gradually built up, starting with an exceedingly thin film. Thus it is that alloys of metals may readily be formed at room temperatures by electrolysis, whereas under ordinary conditions the alloys would not form at all, or would form but very slowly. The fact that platinum will not amalgamate with mercury under ordinary conditions, and that platinum amalgam may readily be prepared electrolytically, is a good illustration of this.

In the case of any plated article, the deposit and the metal underneath continue to act upon each other, or mutually diffuse into each other. This action is great between zinc and gold or lead and gold, as has been stated above. Between copper and gold and brass and gold it is less noticeable. And yet who has worked with brass, gold or platinum-plated weights and has not noticed that the plating is, after all, but a relatively poor protection against corrosion? Especially as the weights grow older they are all the more easily corroded by moisture and traces of salts in the atmosphere of the laboratory. If the plating is heavy, this corrosion will, of course, not take place so early as when the coating is thin, which is so frequently the case.

The mechanical character of the alloy formed by the deposited and the base metal is also of practical consequence. If the alloy has a strong tendency to become crystalline, or is brittle, or has a considerably different co-efficient of expansion from that of the pure metals, the deposit is more apt to chip off than if the alloy is pliable and does not exhibit tendency to crystallize.

Nickel may be successfully plated on copper and its alloys—brass, bronze, etc.—for with these nickel alloys readily. On the other hand, when an object of lead is to be nickeled, it is first copper plated, and then the nickel is deposited on the copper. In this operation use is made of the fact that copper alloys readily with nickel, and copper alloys better with lead than does nickel; and so copper serves here as a cement, as it were. Many other similar illustrations from practice might be cited.

In general, then, metals that will alloy readily with each other may, other things being equal, successfully be plated on each other. Whether the plating will be absorbed faster or slower will depend on the character of the metals and the temperature at which the object is kept, as noted above. If the deposit consists of a metal of the same color as the base metal underneath, as, for instance, gold over brass or copper, the effect of this diffusion of the metals into each other will not be so apparent as when the metals are of different hue—gold on lead or zinc. And yet metals of very different color may at times be plated on each other, and the effect of this diffusion remains unnoticed because the alloy formed has the color of the plating even up to very high concentrations of the alloy. Nickel on copper is a good illustration of this.

While it thus appears that a strong alloying power is desirable between base metal and electrolytic deposit, as it tends to secure good adhesion of the latter, it is also evident that this tendency to form an alloy frequently militates against the very purpose for which the electrolytic deposition was made, namely, to secure a better appearance or to protect from corrosion. It is evident that in the long run all plated objects must slowly deteriorate, even when not in use and when carefully protected from the atmosphere by a lacquer of some kind. The electroplater must study the subject carefully so as to plate those metals or alloys upon each other that possess suffi-

cient affinity to coalesce well and yet will, at the temperatures at which the plated objects are to be kept, diffuse but very slowly into each other. He will also choose the color of the metals or alloys so that the final alloy formed may have the same, or nearly the same, shade as the electrolytic deposit and will itself be corroded less readily than the base metal alone.

The connection between soldering and electroplating of metals is evident from what has been stated. So, for instance, the difficulty of plating on aluminium and of soldering the metal go together, though, of course, the fact that this metal is readily oxidized, and that the oxide coating interferes with both processes, must not be lost sight of. It is not so easy to solder iron with the usual half-and-half solder, as it is to solder zinc, though the latter metal is much more readily oxidized than iron. The explanation is clear: iron does not alloy as readily with the tin and lead solder as does zinc.

A careful, systematic study of the electrolytic deposition of the metals from the standpoint of the alloys formed will no doubt yield results of further practical value.

Laboratory of Physical Chemistry,
University of Wisconsin, Madison.

## THE SMELTING OF IRON ORES AND THE PRODUCTION OF STEEL IN THE ELECTRIC FURNACE.

By Marcus Ruthenburg.

The application of electricity to the smelting or iron ores or the production of steel, either from the ore or previously smelted pig iron, is not a matter of merely recent endeavor.

Attempts, more or less successful, have been made for a number of years in this direction, more especially in Europe, where proper fuel was deficient or too costly, and where water-power, cheap in comparison with available fuel, could be readily obtained.

Therefore, it has been broadly stated, that it was only in such an environment that the electrical production of pig iron or steel could be carried out, upon a commercially successful basis.

In this country, near Niagara Falls, there has been for several years, in intermittent operation, a plant for the production of special alloys of iron. The operator of this plant, in a lengthy and learned article, in a recent issue of *The Iron Age*, went into the subject of the smelting of iron ores electrically, exhaustively, and proved theoretically and practically, that it required the continuous expenditure of 200 horse-power, to produce one ton of metallic iron in twenty-four hours. In other words, that it required 4,800 horse-power hours. Stassano, in Italy, claims to smelt a ton of finished product with 3,000 horse-power hours. De Laval, in Sweden, calls for 3,500 horse-power hours, and Rossi at Niagara Falls uses 4,800 horse-power hours. I have thus set forth what the more prominent experimenters and operators have claimed for themselves, not with the object of invidious comparison, but to state clearly what you might call the condition of the art.

In France, three separate and distinct plants have more recently been put in operation with power consumption differing not materially from the above.

How their conclusions as to power consumption have been arrived at, is a detail that none of them have enlightened the public upon. More than likely it has been done by taking periodic readings of voltmeters and ampèremeters, which is far from conclusive, as both volts and ampères are given to fluctuations, both sudden and excessive, leaving to the one taking the readings the exercise of his judgment as to what the reading should be.

Using a recording watt meter is the only way that this power consumption can properly be arrived at. It takes cognizance of pressure, current and time, and all the attendant has to do is to read his meter and weigh his product.

Before describing some of my own work in electrical smelting of iron ores, there is another point that I want to call attention to, and that is the cost of electric current per kilowatt hour, or per horse-power hour. So many people are in the habit of pointing to Niagara Falls as the place of all places, to secure an unlimited supply of electric current, at economical, if not cheap prices. Cheapness must always be comparative, that is, something is cheap, when of equal quality it can be produced for less in one place than another.

I have long asserted that in their anxiety to get something for nothing, engineers have rushed to remote and out-of-the-way places to capture a promising water-power, and ignored what could be accomplished with large steam actuated electric units.

Let any of these gentlemen figure up what a kilowatt hour can be produced for, based upon the coal consumption and cost of operation and maintenance of a 1,000 or still better a 5,000 kilowatt unit. He will then find that a fair quality of coal, with the facilities that any large plant would of necessity be provided with, will put the prices now asked by prominent water-powers, very much in the shade.

My own work in the electrical smelting of iron ores has been of a practical nature, and my efforts have been bent to the accomplishment of the work upon a basis that would not only permit of universal use of the method, as an offset to blast furnace and open hearth steel practice, but would also produce superior metal at a materially less cost. In a nutshell, this statement resolves itself into a question of how much power I use to accomplish my work, and in a nutshell

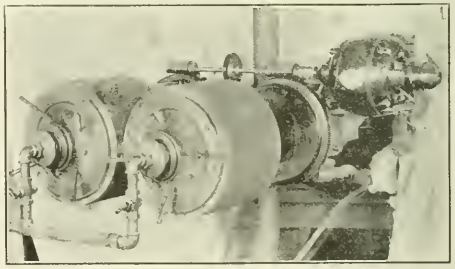


FIG. 1.—VIEW SHOWING BRIDGE OF ORE BETWEEN ROLLS.

the answer is, less than 500 kilowatt hours to produce a ton of product.

Some very learned gentlemen have undertaken to prove that "this was not possible"—that "it was an unheard of efficiency," and that "even if it were so, the vast stores of high-grade ores at our command and the efficiency of the blast furnace made the man who offered to replace the blast furnace simply a happy optimist." To these gentlemen let me simply say, show me the supply of high-grade ore, open to the independent operator, and I will undertake to "make him rich beyond his dreams of avarice." As to the economy of the blast furnace the same learned gentlemen will agree with me, that of the ton of coke, which even good practice requires to make a ton of pig iron, but a little over 300 pounds are required for the chemistry of the furnace, *i. e.*, reducing the iron. The balance is required to melt not only the reduced iron, but the medley of earths and the lime which go to form the cinder. An important portion is also consumed in the production of waste combustible gas, some of the value of which is recoverable under boilers and in the stoves for preheating the blast. As against this, what is a fair statement of the operation of an electric furnace producing a ton of metal with a consumption of 500 kilowatt hours.

The 500 kilowatt hours will require the combustion of 1,000 pounds of soft coal (not coke). The reduction of the ore will

require 300 pounds of carbon = 700 pounds of fuel, saved at the outset. At the present abnormal prices of coke and coal any comparison of price would not be of any particular moment, though ordinarily coke costs about twice as much as coal. Suffice it to say, you melt your ore with cheap coal as against costly coke, and further, you do it with the saving of 33 per cent. of the fuel's weight. Of course, the question that interests any one conversant with these matters is, how do you effect a saving of 80 per cent to 90 per cent. in power, over what others have done in the same field. Apparently I do—but I don't. The truth is—we don't do the same thing.

It has been and is (with the exception of my method) the practice to melt the ore and maintain it molten, the molten mass being a path of low resistance for the passage of the current, in which reduction takes place by the hot carbon of the electrodes and the gases of carbon given off. To maintain this mass molten requires the large expenditure of energy. Instead of this my work consists in holding the ore (but a small portion at any one instant) by a powerful magnet. Only the portion held by the magnet is melted, the ore supply from above resting upon the magnetic bridge and being thereby restrained from slipping through. The poles of the magnetic circuit are also the poles of the melting circuit. Electrodes, there are none, the resistance being the ore itself, which as fast as fused is carried out of the zone of fusion and dropped, its place being taken by ore from above.

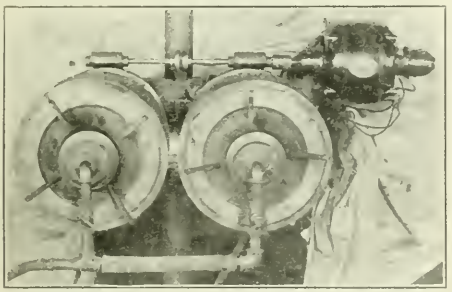


FIG. 2.—FRONT VIEW, SHOWING BRIDGE HEATED, 700 AMP., 50 VOLTS.

Preparatory to the electric furnace, the ore should be cleaned up to the highest possible point, so as to avoid the treatment of useless earthy and cinder-forming matters. Magnetic ores may be quite lean and yet pay to crush and clean. In some cases the crushing must be quite fine to produce economic results. This iron dust cannot be used in a blast furnace, but is just what the electric furnace wants, the finer the ore the more intimate the mixture of the charge may be and the more thorough the reduction.

The ore is mixed to produce the desired chemical analysis of the finished material and the required reducing material is incorporated. At the high temperature of the electric furnace the charge is fritted into a homogeneous mass, minus a large part of its oxygen, and is discharged from the furnace very hot and kept hot so that the cementation may finish the elimination of the contained oxygen. The material is then ready for melting in an open hearth furnace and is steel.

The accompanying pictures are photographs of a furnace now in operation.

A little study will show the horizontal horseshoe magnet, divided and insulated (electrically) at the bend of the magnet, the supporting post forming the pin of the hinge joint. The magnetic poles are within the bronze revolving rolls against whose surfaces the melting is done. They are water-cooled. The rolls are driven at four revolutions a minute by the small motor and the worm gears, making roughly, 16 feet of peripheral speed a minute.

## THE ABUSE OF ELECTROPLATING.

By H. L. HAAS, PH.B.

Electrometallurgy has, until very recently, been wholly in the hands of unscientific men, workmen who have never given it the proper attention as a science.

Formerly very little attention was paid to the composition of a plating solution, nor what chemical changes took place in it during electrolysis. When a solution did not deposit its metal properly, the plater thought it needed a handful of this or a spoonful of that, and threw it in, not knowing whether it was soluble in the solution or not or what change was produced. And when that did not work, he thought perhaps it needed another handful or spoonful of something else, irrespective of any exact quantity or what the chemical change would be by the addition of it. And when it still did not work he was at a loss what to do further, so did the only thing possible—threw it away and started to make a new one (because he was a plater and not a scientist). But the new solution was no better than the first. And why? Because he had made it with a handful of this and a spoonful of that and an unknown quantity of something else that he had forgotten the name of (because he was a workman and not a scientist).

If he bought certain chemicals, the nature of which he did not know, or what percentage of purity, he was again in trouble when his solution did not work properly, because he had made it in a careless manner with only a workman's knowledge.

He had electric current, to use his expression, yet the solution did not deposit. He knew only that he had a current, because when he connected the positive and negative wires he obtained a spark.

The platers' voltmeter was formerly an old, rusty file, which they used to put across the two wires, making the connection and obtaining a spark. Then they knew they had electric current, but they did not know or care how much they had, because they had never measured it.

Electroplaters should know the following in order to be thoroughly conversant with their work:

First. Exactly what the depositing solution is made of.

Second. What takes place in the solution during the action of the electric current.

Third. What chemicals they are using, their properties and purity.

Fourth. The solubility of the anodes.

Fifth. How much electric current is necessary to deposit the metal properly; how many volts and ampères are employed.

Sixth. How much resistance the solution and anodes offer to this electric current.

Seventh. The distance between the cathodes and anodes, and whether it varies.

Eighth. The amount of metal that is dissolved in a given time by the action of the electric current on the anodes.

Ninth. The amount of metal that is being deposited on the cathodes.

In this manner the plater is in a position to determine at all times what is going on in his solution, and if anything is wrong can obviate the difficulty, because he knows instantly the remedy for it.

For example, as in the case of silver and gold, the best plating solution is composed of cyanide of silver or gold. Cyanogen is evolved at the anode and silver or gold, as the case may be, is deposited upon the cathode. Chemicals used for making these solutions are cyanide of potassium and chloride or nitrate of silver or gold, or cyanide of silver or gold.

It is a known fact that, when subjected to the electric current, these two metals are dissolved very rapidly at the anode. The consequence is, when plating with them, very small anodes are all that are requisite to keep the metallic strength of the solution up to the proper standard.

In the case of copper and brass, which do not dissolve in

[illegible] platinum, is readily as the two former metals when subjected to the action of the electric current, a larger surface of these two metals should be employed as anodes than in the case of silver and gold.

With nickel, it is a known fact that this metal is only with great difficulty soluble in sulphate of ammonia (which is the regular solution used for nickel plating) by means of the action of the electric current, and as a consequence the largest possible surface of nickel anodes should be employed.

It has been practically demonstrated that the maximum plating surface of nickel anodes that can be placed in a tank of a given size, even when suspended on both sides of the cathodes, were not sufficiently dissolved by the action of the electric current to give the same amount of metal to the solution that was deposited upon the cathode, consequently the solution would in time become too weak in metal; therefore a larger surface of nickel must be placed in the bath, and the only manner in which this can be accomplished is by adding metal in some form to the solution. Formerly this was done by means of the addition of fresh nickel salts dissolved in the solution, which was both detrimental and expensive. Then the corrugated nickel anodes were invented, and it was practically determined that if one-third more surface of nickel was subjected to the action of the electric current in a nickel solution, the same amount of nickel would be dissolved into the solution as was deposited on the work, and as a consequence the solution remained almost constant in metallic nickel, thus obviating the addition of metal in any other form.

I advocate that all plating solutions should be made as simple as possible. By this means the plater, knowing at all times what is taking place in his solution, can readily remedy any error. But if the solution is complicated, and there are various chemicals that really have no special advantage, should the solution go wrong the plater is at a loss to know where the trouble lies, and therefore is apt to ruin his solution in trying to doctor it.

I have been endeavoring for many years to bring this up to a scientific standard, and with many gratifying results.

At the present time platers are giving more attention to the composition of their solutions. They weigh their materials; they endeavor to acquaint themselves with the action that the electric current produces on a solution; they pay more attention to the electrical contact, their different connections, the advantages of keeping them clean and free from all corrosion. They are using voltmeters and ammeters for measuring their electricity, switchboards for reducing their current to the proper and best point for the proper deposition of the metal, and I am pleased to say that the results which are now obtained in plating of the various metals are far better in every way than formerly. And I feel confident it will only be a few years when it will have reached the high standard of other sciences.

## THE PHYSICAL CHARACTER OF METAL DEPOSITS.

By Prof. C. F. Burgess and Carl Hambuechen.

IN the passage from a liquid to a solid condition a substance usually assumes a crystalline structure, the form of which is influenced by various factors, such as chemical composition, temperature, density, etc. Electrodeposition is the passage of metals from the state in which they exist in a solution to a solid state through the aid of the electric current. In passing an electric current through an aqueous solution of a metal salt, the metal in the solution is caused to separate out, changing its physical condition and developing properties of cohesion between metal particles thereby deposited. The amount of cohesion between metal particles after separation from the solution varies through a wide range, depending upon the various conditions of operation. Under certain circumstances, the metal may assume regular geometrical forms or crystals, and, in fact, metals are almost invariably deposited in such forms. Although to the eye a deposit may appear amorphous, under the microscope it may be shown to consist of a great number of minute crystals in juxtaposition.

The appearance and character of a growth of metal is determined to some extent by the size and shape of the crystals and the manner in which they build up. They may assume innumerable forms, all the way from spongy and almost gelatinous masses to coarse crystalline and dense structures. With suitable conditions of current, solution and

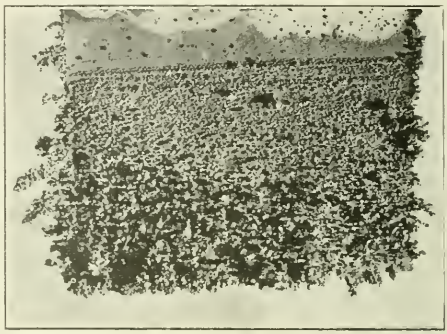


FIG. 1.—ZINC DEPOSIT.

metal, growths may be produced which will assume almost any of the forms of plant vegetation, to which they may perhaps be best compared. A photograph of a copper deposit might, with suitable background, be mistaken for a tree in the winter time, with trunk, branches and twigs. Various kinds of trees may also be produced in miniature with such exactness as to show the formation of buds and leaves upon them. The grasses, ferns and mosses may be produced in form in a similar manner. So much do these forms resemble plant growth that the term metallic vegetation has been applied to depositions of metals which are produced by electrolytic means.

A study of the conditions under which various forms of

FIG. 2.—COPPER DEPOSIT.

metallic vegetation can be cultivated is very interesting and a promising field for research, inasmuch as the exact conditions for the growth of various kinds of formation are very little understood. From the practical standpoint, the study of these growths is important, not so much as showing how they may be cultivated, but rather how they may be suppressed. It is not branches, twigs and outgrowths that the electroplater or electrorefiner wishes to obtain, but rather roots and a dense undergrowth. Knowledge as to how the conditions may be regulated so that this may be effected governs the success of many technical processes. The factors determining the forms of deposits and those which the metal depositor has in his

power to regulate are the following: Chemical composition, concentration and temperature of the solution, the current density and circulation.

The accompanying illustrations are taken from photographs of metal deposits, and illustrate a few of the typical formations which are frequently obtained. Fig. 1 shows the shrub or fern-like growths of zinc. Fig. 2, the larger tree crystallization of copper. Fig. 3, a reproduction of the growth around the edge of the cathode receiving an iron deposition. Fig. 4, the appearance of crystalline lead as deposited from a lead acetate solution.

The most important factor in regulating the quality of the deposit is the composition of the solution. As is well known,

FIG. [illegible] IRON DEPOSIT ON EDGE OF CATHODE.

the deposit obtained from a nitrate, sulphate, chloride or other solution of a particular metal is to a large extent characteristic of the particular solution used. The presence of certain substances added to a metal solution will also influence the kind of deposit, sometimes for the better and often for the worse. Aluminium sulphate added to a zinc sulphate solution affords a marked improvement in the quality of zinc deposit, although the aluminium sulphate itself undergoes no chemical change. A small quantity of carbon bisulphide in a silver plating solution enables a polished coating to be obtained, whereas when omitted the surface would become rough much more quickly. A similar effect may be produced by introducing a very small amount of gelatine into a nickel-plating solution although if the amount exceeds a certain very small quantity the coating will be rendered worthless. The importance will, therefore, be seen of not only paying attention to the chemical composition of the solution, but to its purity as well.

At the present time there seem to be few guiding principles showing what substances may be introduced to a metal solution to advantage, and what substances should be avoided. The physical character of the deposit, being so greatly influenced by the quality of the solution, seems to indicate that the solution itself has some physical structure, such as a peculiar arrangement of molecules or other physical characteristics, which determine what the character of the deposit obtained from it will be. If the solution has some cellular structure which would correspond to the crystalline structure of solid we would have some explanation of the marked influence on the quality of deposit which the introduction of some foreign substance to the solution will exert, inasmuch as the structure of the solution itself would be influenced thereby. There seems to be some grounds for the belief that the viscosity and surface tension of a solution has some relation to the quality of the deposit, and that if we add a substance to a metal salt which will alter the above properties the quality of the deposit may be thereby influenced.

A fact that is worthy of note, and which may explain the differences in the results obtained by different experimenters, and the difficulties which have frequently been encountered in reproducing effects which have previously been obtained, was brought out in some work being carried on by Mr. C. L. Zimmerman in the electrochemical laboratory on the deposition of zinc. He found that the kind of deposit which was obtained from a zinc sulphate solution prepared by dissolving crystals of zinc sulphate in water was materially different from the deposit obtained under similar conditions of temperature, current density and content of solution, in which case, however, the solution was prepared by dissolving pure zinc in dilute sulphuric acid until it became of the same neutrality as the solution obtained by dissolving the crystals. A similar characteristic has been noted in the deposition of iron from sulphate solutions made by dissolving iron sulphate in one case, and iron in sulphuric acid in another. It has further been found that the boiling of a solution and the subsequent cooling to room temperature may also materially change the character of the deposit.

The effects of concentration of solution, temperature and current density have been more carefully investigated than has the effect of the chemical and physical nature of the solution, and it is not the purpose to deal here with those factors.

In the deposition of metals for ornamental and protective purposes it is not only important that the metal deposited shall be firm and uniform throughout the entire surface, and that the particles of metal shall have considerable coherence among

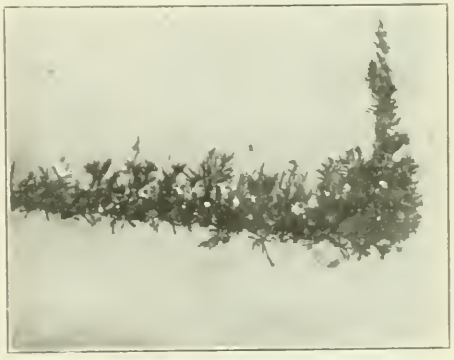


FIG. [illegible] [illegible] OF ZINC.

themselves but what is equally important, there should be a strong cohesion between the metal particles deposited and the metal surfaces upon which they are deposited. This, as is well known, depends very largely upon the surface cleanliness which influences the intensity with which metals deposited upon the same will adhere. It also depends to a certain extent upon the metal receiving the deposit and the metal being liberated.

The fact, as shown in the preparation of metal [illegible] certain metals have greater affinity for each other than for certain other combinations, seems to make itself evident in the cohesion or attraction between the metal which is [illegible] deposited and the metal receiving it. It is held by some that

for the best adherence there should be a true alloying at the surface separating the two metals, and this appears to be borne out by microscopic examination of certain deposits. Zinc may form a very adherent coating on copper, due to the fact that the zinc alloys with the copper surface to a certain extent, and the poorer adhesion to iron may possibly be accounted for by a lesser affinity between two metals or, in other words, a lesser tendency to alloy. Gold will alloy very readily with zinc at ordinary temperatures, as shown by the very striking observation that a gold coating applied to a zinc

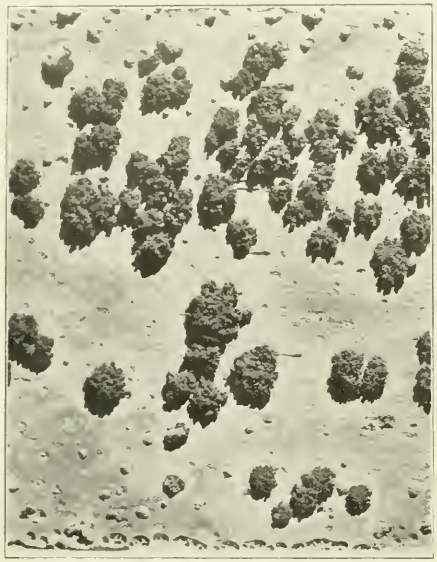


FIG. 5.—MOSS-LIKE GROWTHS ON ZINC CATHODES.

surface will in a few days entirely disappear, being absorbed by the zinc.

This alloying phenomenon, however, cannot be held as a universal one, for there are certain contradictory facts which must be taken into account. In many cases, one of which is the deposition of nickel on iron, there is no evidence for claiming that there is an alloying of the two metals, although a good adherent coating may be obtained. Further, if there is a tendency to alloy, it might naturally follow that the alloying would proceed indefinitely, and that the degree of adherence of the coating would increase with time. It is a matter of common observation, however, that many electrodeposited coatings become less adherent with time.

In fact, the theory of the alloying of the surface is not necessary in explaining the tenacity with which one metal will adhere to another, but a more satisfactory explanation is probably found in the direct cohesion which is established when solid particles are brought into intimate contact. Copper may be deposited in such a way that a cohesion between the copper particles themselves may be so great as to resist a force of 25 tons per square inch or over to separate them. If a copper particle is brought into intimate contact with an iron particle, a similar cohesion, though perhaps less in degree, will result. On this basis, therefore, it is desirable that in the electroplating processes the deposited metal should be brought into as intimate contact with the surface receiving the deposit as is possible. The adherence of a coating, as a consequence, will depend upon the amount of surface which is to be brought into contact.

It is well known that a surface which is somewhat rough will receive a more adherent coating than will a polished surface, and this is undoubtedly due largely to the greater amount of actual surface per superficial area which is brought into contact. Upon this supposition of the desirability of intimate contact of metal surfaces, the influence of the electrolyte on the adherence of a deposit may be explained. A surface which has had the proper physical treatment to prepare it for receiving a coating may have the appearance of being perfectly polished, but an examination by the microscope will reveal the fact that the surface is made up of minute particles with crevices between them. If, on immersing this surface into a plating solution, the solution penetrates into such crevices by passage of electric current, the metal will be deposited upon every point exposed to the solution. If, on the other hand, the solution is of such a nature that it will not go into these minute crevices, in which case the air or other insulating material will be retained therein, it is quite natural to suppose that it will be only the more elevated points which are in contact with the electrolyte. These points will receive the deposit, which will grow sidewise from these projections until the cavities are bridged over and the entire surface has the appearance of being coated. In this case it will be evident that the adherence of the coating will not be as great as it will be where the metal goes into the depressions.

As is well known, some solutions will "wet" a surface much more readily than will others, and in using a solution from which an adherent coating is to be obtained it is desired that the solution shall have the property of most thoroughly wetting the entire surface. Or, in other words, the electrolyte should consist of a solution in which there is a large mutual molecular attraction between the liquid and the metal surface. This property can be imparted to various solutions of metallic salts by the addition of certain other soluble substances, and

FIG. 6.—ROUGHENING OF IRON DEPOSIT.

it is for this reason that such additions are frequently practiced. It is easily shown that a coating of copper obtained by immersing aluminium in a copper chloride solution is very nonadherent, and may be readily brushed off; but that if an alcoholic solution of the same copper be employed, the coating is much more firmly adherent. This may, therefore, be explained on the supposition heretofore advanced that alcohol causes the copper solution to come into more intimate contact with all parts of the aluminium surface. In this connection, an investigation of the relation between the surface tension of solutions and various metallic surfaces upon the adherence of the coatings obtained would undoubtedly lead to some interesting results, and might establish guiding principles in the design of plating solutions.

The peculiar characteristic of all deposited coatings is that, no matter how dense, coherent and smooth the metal surface deposited may be, the cohesion and smoothness decrease with

time, and the surface eventually becomes rough. This is a serious limitation where thick deposits are desired, as in the electrolytic recovery and refining of metals.

Fig. 5 illustrates the appearance of moss-like growths on zinc cathodes. Fig. 6 illustrates a roughening of an iron deposition, and a phenomenon which frequently is observed is here shown, namely, the grooving or furrow characteristic. These grooves, which are almost always obtained in a vertical position, are due to the fact that the solution in the immediate neighborhood of the cathode, becoming depleted in metal, decreases in density and rises to the surface of the tank. The rising solution is, by the formation of small projections near the bottom of the anode, split up into columns of dilute solution, separated by columns of more dense solution. The electric current, finding a more ready path through the dense solution, deposits the metal more readily therefrom, and thus starts the ridges, after which the action becomes more pronounced. The remedy for this defect will be at once evident,

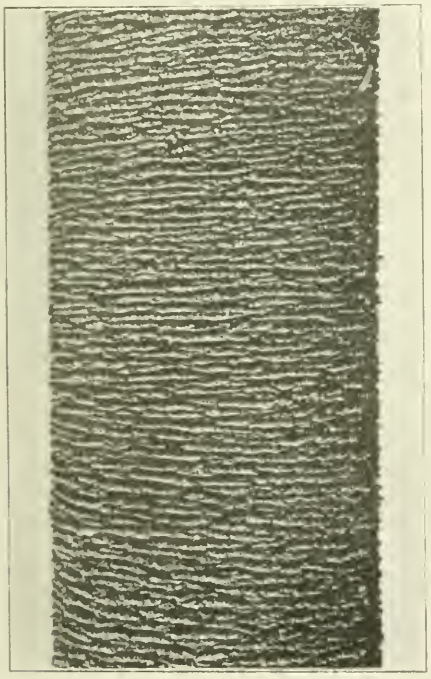


FIG. 7.—HORIZONTAL GROOVING, OBTAINED BY ROTATING A CYLINDRICAL CATHODE AROUND A VERTICAL AXIS, ZINC DEPOSIT

for, if the solution be agitated by stirring or other means, it may be prevented. This vertical position of the grooves is due to the fact that it has the same direction as the flow of the solution. An interesting example of horizontal grooving is illustrated in Fig. 7, where a cylindrical cathode was rotated around a vertical axis while receiving a deposit of zinc.

Fig 8 illustrates another effect which is frequently developed in electrodeposition, namely, the pitting or perforation of the metal. Perforations may be caused by the presence of insulating particles on the surface receiving the deposit by the deposition of particles of foreign substances which may be floating around in the solution, or by the liberation of bubbles of gas, which may adhere to the cathode. This defect is most commonly caused by the liberation of gaseous products, and the remedy is the choice of a solution from which such gas will not be liberated or by circulation or agitation of the solution.

These bubbles of gas, usually consisting of hydrogen, which may adhere to the cathode surface in sizes varying from most minute dimensions to one-eighth of an inch in diameter, insulate the surface at such points, and the metal may be built up around them, even completely inclosing them. This results in a porosity and inclusion of gas frequently found in deposited metals. Fig. 8 illustrates such pitting, and the wavy form which the metal takes around the lower portion of some of

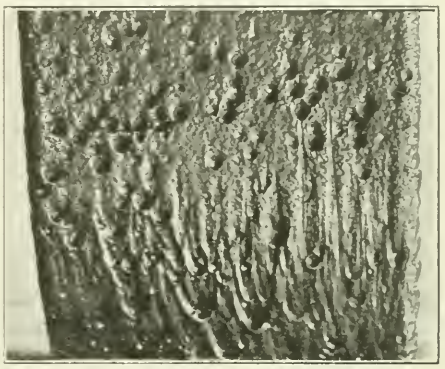


FIG. 8.—PERFORATION.

these cavities indicates the way the solution divides and flows around the obstructing gas bubbles.

Another peculiar property of electrolytic deposition, and one which makes itself particularly manifest in the separation of nickel, is the distortions in shape which certain deposits take after the deposition has proceeded to a certain thickness, or upon subsequent heating or other treatment of the metals. This is due to the strains which are set up during the process of deposition from the solution. It is claimed that nickel

FIG. 9.—NICKEL COATING, PEELING OFF.

deposited on a thermometer bulb will tend to contract with force sufficient to compress the glass and cause the mercury column to rise. This property becomes prominent in nickel plating where the coating is allowed to exceed a given thickness. These strains are such as to cause the nickel to tear away from the surface being plated, as is illustrated in Fig. 9.

LABORATORY OF APPLIED ELECTROCHEMISTRY,
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## HISTORY AND PRESENT DEVELOPMENT OF ELECTROLYTIC NICKEL REFINING.

By Titus Ulke.

Probably the earliest attempt to electrolytically separate nickel from its alloys or matte, in any continuous or semi-continuous process of refining such substances, was made by Emil André, who obtained a German patent, No. 9,048, of November 1st, in 1877. André's process consists, briefly, in suspending nickel-copper bearing material, cast into plates, as anodes in an acid solution, and electrolytically depositing out most of the copper on cathode plates of sheet copper, and finally the balance of the copper on such plates, with carbon anodes put in place of the nickel copper anodes, this deposition occurring necessarily under varying and, therefore, in my opinion, commercially impracticable chemical and electrical conditions, then withdrawing the entire solution thus freed from copper, and recovering the nickel from same, after removal of any iron it contains and making it ammoniacal, by electro-deposition of the nickel on suitable cathodes and with (evidently unsuitable) anodes of ordinary iron or zinc. This process was tried in Germany and abandoned.

Not daunted by this and other failures, patents were obtained by Messrs. Basse & Selve, Ricketts, Hoepfner, Frasch, Browne, Ulke and others for the electrolytic separation of nickel or nickel salts from combinations of nickel with other metals or metalloids, and in some cases from ore, and works in Germany, Wales, Canada and the United States were erected, using processes based on several of these patents. In the following pages I shall now describe these interesting refining plants, to which visitors are almost invariably denied admission, as fully as the rather meagre data at my command will permit, treating the Vivian, Balbach, Cleveland, Hamilton and Papenburg Electrolytic Nickel Works in turn and ending with a discussion of the proposed copper and nickel refinery at Sault Ste. Marie.

### I. Vivian's Electrolytic Nickel-Copper Separating Works.

In 1892, according to Mr. A. F. Weightman, who kindly furnished me with the following data, H. H. Vivian & Co., of Swansea, Wales, started a new electrolytic copper refinery in connection with their nickel, cobalt and copper works, and introduced the recovery of nickel as a special feature of this plant.

In treating ores from Sudbury, Canada, containing nickel, cobalt and copper, by the "wet" process, at a certain stage of the latter large quantities of "residues" were obtained, which were melted down into anodes for electrolytic separation. These anode plates of nickel-copper alloy were placed in lead-lined depositing tanks, containing an acidified solution of copper sulphate, opposite copper cathodes. On passing an electric current, copper was alone deposited, and the solution therefore became richer in nickel and poorer in copper, until it was eventually withdrawn and treated especially for the recovery of the nickel.

The plant erected in Swansea was designed for the treatment of 10 tons of copper and nickel per week, but it never reached its full capacity, for reasons discussed later.

The anodes contained about 60 per cent. Cu and 40 per cent. Ni. As each pair of regular anodes and cathodes had one or two intermediate plates suspended between them, in series circuit, the system of refining used was based on a combined multiple and series arrangement of electrodes.

Forty tanks, loaded with plates thus arranged, and worked at a current density of 10 ampères per square foot, were installed, together with 10 tanks, known as "finishing" tanks, which were provided with lead anodes for the purpose of removing the last traces of copper from the solution.

The main tanks were arranged in pairs and each pair was supplied with solution independently. It was the company's aim to obtain good reguline copper in these tanks and to run off a liquor containing nickel and copper in the proportion of 9 to 1 into the finishing tanks, which would yield non-reguline copper. Experience soon showed, however, that this object could not then be attained, as the copper deposited in the main tanks was of a more or less non-reguline character and frequently "treed across" to the anode or to anode side of the "intermediate" plates and short-circuited the tanks. These tanks had to be repeatedly cleaned out on this account, and constantly required one man's time testing them with some form of voltmeter for short circuits. Whenever a tank short-circuited, the amount of copper in the solution escaping deposition in a given time and run into the finishing tanks, would quickly overtax the capacity of the latter. In the finishing tanks, as had been expected, the copper came down as a black, bulky powder, which accumulated in the bottom of the tanks rapidly and soon short-circuited the cells. In consequence it became necessary to clean them out every day, until a scheme to be described presently was adopted. The difficulty with short circuiting was so great that the actual output of the refinery was always much below its designed capacity, and this defect was further exaggerated by trouble with the dynamos. In those days British dynamo manufacturers were only accustomed to making machines for lighting purposes, in which the generator was only taxed to its full capacity for a few hours during the day, and ran the rest of the time on a light load. The result was that the machine supplied to the above works was quite inadequate to maintain a full load for weeks at a stretch and gave constant trouble during early stages, although more or less satisfactorily remedied subsequently.

The trouble from short-circuiting was considerably lessened by the following scheme introduced by Mr. Weightman in 1893, and recently patented, I believe, by Dr. Keith. As the solution in the finishing tanks got weaker and weaker in copper, the current density was continuously decreased, and this resulted in obtaining a more reguline deposit of copper and also in lessening the proportion of the refinery current wasted in evolving hydrogen, which occurred freely by the old method. Even with these improvements, the liquor could seldom be obtained sufficiently free from copper, i. e., with not over 0.1 per cent. Cu, which was the maximum allowable. Consequently the last traces of copper had to be "gassed down" with hydrogen sulphide, involving trouble and expense, and defeating largely the object of the process. Short-circuiting was also checked by casting the anodes somewhat smaller than the cathode sheets. This disposition not only removed the anode from that part of the system where "treeing" was the worst, namely, at the edges of the sheets, but it also checked the tendency to tree for the following reason: The distance the electric current had to travel from the edge of the anode to the edge of the cathode, since it had to take an oblique path, was greater than the distance between any other opposed portion of the electrodes, and consequently the resistance was greater. Therefore the current density at the edges was less than on any other part of the cathodes and the "treeing" was consequently checked.

The method adopted for stripping the cathode sheets from the cathode pattern plates consisted in varnishing the latter with a weak shellac varnish containing about 1 pound of shellac to 1 gallon of alcohol, which gave a coating sufficiently thick to prevent the copper deposited over it from sticking, and at the same time not thick enough to insulate the cathode from the passage of the current. The edges were dipped in "Brunswick black," and the pattern plates thus prepared, were hung in the cathode starting tanks to receive their copper deposits and form sheets, which were then easily detachable from their pattern plates.

An ordinary electric bell was found very convenient for testing the voltage of the cells. This bell was specially wound so as to ring at its ordinary loudness when the cells were at the correct voltage. If the bell rang more or less loudly it was a sign of either dirty contacts or short-circuiting in the particular cell under test. It was astonishing how exactly a man could tell the condition of a cell with this simple instru-

ment, and how much more it appealed to the average workmen than a delicately pivoted and expensive voltmeter.

In carrying out the above separating process, a very large amount of anode scrap was produced, which was expensive and troublesome to remelt, because of the high melting point of the Cu-Ni alloy. The amount was diminished by casting the anodes about 1/8 inch thicker at the top than the bottom (accomplished by setting the molds a little out of the level), and thus checking the tendency for the anodes to be eaten away at or near the surface of the electrolyte. The anodes were cast in closed molds and weighed about 80 to 90 pounds apiece. It was considered inadvisable to exceed this weight as most of the work in the cell room (in common with most English refineries) was done by manual labor, and any weight over 80 to 90 pounds was inconvenient to handle.

The copper-sulphate electrolyte was obtained by dissolving roasted matte by well-known methods and adding an excess of about 10 per cent. free sulphuric acid. The purified nickel-sulphate liquor from the cells, practically a saturated solution, was run off and boiled down until the anhydrous nickel sulphate separated out. This was then roasted to oxide and reduced to metal by carbon, although it was intended to eventually recover the nickel in a much purer state by electro deposition.

Small quantities of platinum were obtained in the anode slimes, but never in sufficient amount to be of appreciable account on the cost sheet.

The success of the above-described process was not considered sufficient to warrant its permanent establishment, and in 1894 the refinery was therefore closed.

### II. Balbach Electrolytic Nickel Refinery.

The largest and most successful electrolytic nickel refinery up to date appears to have been the one at the Balbach Works, Newark, N. J., erected in 1894 and operated until 1900, under the superintendence of Mr. F. A. Thum, who is believed to have originated the process employed there. Although this process has been jealously guarded as a secret by the Balbach company, and the exact conditions under which nickel refining may be successfully carried out practically were independently investigated and first published by others, the credit of being the pioneers in the commercial electrolytic refining of nickel as well as of copper in America undoubtedly belongs to the Balbach firm.

The analysis and mechanical tests of samples of nickel cathode made at the above works and seen by the writer indicated that the cathodes were remarkably pure and strong. The total absence of such elements as carbon, silicon and sulphur in the electrolytic product was accompanied by such good physical properties, particularly in the way of increased ductility, malleability and tensile strength, as to make it far superior in these respects to any fire-refined nickel I have ever tested. The only impurity, besides cobalt, found in the Balbach nickel was iron, and this only up to 0.25 per cent., which is certainly remarkable, in view of the close electrochemical relationship existing between these elements.

Although I had no occasion to see the Balbach plant in actual operation or to get any official information as to the composition of the electrolyte employed, I am convinced that the metal was produced by a process quite like that proposed by Prof. Foerster about three years ago in a communication published in the *Zeitschrift fur Elektrochemie*. In this process solid plates of pure metal to any required thickness may be deposited from neutral sulphate solutions heated to from 50 to 60° C.

The Balbach nickel cathodes had about the same dimensions and shape as the copper cathodes from the company's multiple system copper refining plant, showing that the same system and apparatus were probably applied in the refining of both metals.

The crude nickel anodes, assaying from 94 to 97 per cent. Ni, were furnished by the Orford Copper Co., of Constable Hook, N. J., and were reduced from their nickel oxide in a reverberatory furnace. The anode scrap and residues from the electrolytic process were returned to the Orford Works and put back into the nickel anode furnaces, to be returned again as anode to the Balbach Works and reworked electrolytically until the residues were at last rich enough in precious metals to make separate refining and parting profitable.

The above outlined process is not now in use there, as the Orford Co., upon whose nickel material the Balbach Co. were dependent, has ceased shipping crude nickel in the shape of anodes to the Balbach refinery, and is itself producing fairly good metallic nickel, averaging about 99.21 per cent. Ni; 0.66 per cent. C, Si, S, etc., and 0.13 per cent. Cu, by reduction of nickel oxide with carbon. This Orford nickel, however, being contaminated with carbon, silicon and sulphur, is neither as pure, nor as strong as good electro nickel obtained by the above process.

The Balbach nickel refinery was started in 1894, but its operation was discontinued about three years ago for reasons unknown to me, although I surmise that the large production of scrap from the imperfectly smelted and very brittle anodes was partly accountable for its closing down. The taking out of a patent by Mr. F. A. Thum for the electrolytic refining of nickel from metallic powder or granules, such as may easily be reduced from nickel oxide, to obviate the use of cast anodes, seems to point in that direction, and the same object of diminishing trouble with the anodes evidently also underlies the suggestion made by Mr. William Thum, also of Newark, to use slabs of crude nickel as electrodes in a series system, wherein the nickel deposited on the cathode side would make a staunch backing for the crumbling crude nickel of the anode side and thus obviate the difficult casting of anode suspension and contact lugs. It is claimed that electrolytic nickel can be produced from Orford anodes in this way at a cost of less than 1 cent per pound.

Besides metallic nickel, the Balbach Smelting Co. have been a heavy producer of nickel plater's salts. Such salts have been profitably recovered, for the last twelve years, as by-products in processes for the regeneration of its foul electrolytes from the company's copper refinery, the small quantities of nickel contained in the blister copper treated being all retained in the acid electrolyte and, of course, concentrating therein.

The Balbach method of recovering the nickel sulphate consists chiefly in repeated fractional crystallizations and a final removal of the remaining copper by electrolysis.

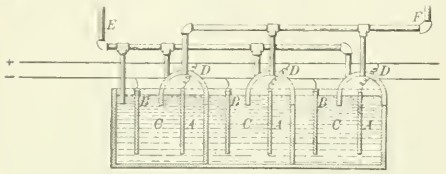
### III. Cleveland Nickel and Copper Refinery.

This refinery developed from an experimental electrolytic plant started six or more years ago in the Brooklyn suburb of Cleveland, Ohio, by the Canadian Copper Co.

The commercial plant, operating under a Canadian patent of Mr. David H. Browne, No. 74,401 of January 14, 1902, reissue of No. 69,729 of December 21, 1900, in 1902 began to produce, and turned out from 8 to 15 tons of electrolytic nickel per month, but closed down several months ago, I presume, temporarily.

Mr. Browne's electrolytic process consists of the following steps: Anodes of copper-nickel alloy and cathodes of pure copper are suspended in a solution of copper-nickel chlorides which is continuously regenerated by passing it through a tower filled with Bessemerized matte or alloy to be treated, in contact with salt solution and chlorine gas evolved from the nickel precipitating process. When the electrolyte is rich in nickel, and the copper nearly all deposited on the copper cathode, the remaining copper is probably gassed down with hydrogen sulphide and removed, the iron precipitated with ammonia and filtered off, and the hot neutral nickel chloride solution remaining, electrolyzed in contact with carbon anodes

in a water-sealed compartment (See Fig. 1.), and pure sheet nickel cathodes. The chlorine evolved from the anode compartment is conveyed to the regenerating tower to assist in




BROWNE'S ELECTROLYTIC PROCESS FOR THE ELECTROLYTIC SEPARATION OF NICKEL AND COPPER.

dissolving additional nickel and copper from the material that is treated. It is rumored that the erection of larger works, operating as above outlined, at a more suitable location, is contemplated.

### IV. Hamilton Nickel-Copper Refinery.

This plant was built about three years ago at Hamilton, Ontario, and consists of a frame tank house, about 40 feet wide and 100 feet long, containing, it is reported, about 40 depositing tanks, laboratory, supply tanks, etc., and storehouses. It was originally built to treat Sudbury ore by the Hoepfner process, but was remodeled later to accommodate the Frasch process and apparatus.

As described in the *Engineering and Mining Journal* of September, 8, 1900, and applied to copper-nickel matte, Frasch's process consists essentially "in the electrolysis of a brine solution, so as to produce caustic soda solution in the cathode section of a divided electrolytic tank, and chlorine in the anode section, in which is placed the nickel-copper matte, the metals in the latter being dissolved and forming chlorides.

"The copper in the solution thus obtained is recovered by electro-deposition, the nickel being separated from the cobalt, iron, and the remaining traces of copper as a double salt of nickel and ammonia, while the caustic alkali is recovered from the solution withdrawn from the cathode section as a by-product. The matte, coarsely crushed, is charged directly on a layer of carbonaceous material in the anode section of the tank, and is covered by a thin layer of sand, which is said to make a very satisfactory diaphragm for the separation of the resultant solutions of caustic soda and the chlorides of the metals. The tank is now filled with brine which is then electrolyzed, and the metallic solution obtained in the anode section and the alkaline solution in the cathode section are periodically displaced by fresh salt solution.

"When it is decided that the nickel-copper matte on the bottom of the tank has received sufficient treatment to require removal of the solid residue, the upper layer of sand is taken out and washed for re-use, and the leached or partly leached material removed."

Hoepfner's and Frasch's processes were both tried within the last two or three years, on a small commercial scale in the Hamilton refinery, but neither of them attained practical prominence. The plant owned by the Hamilton Nickel Co. has at present closed down.

### V. Papenburg Nickel-Copper Refinery.

The Papenburg electrolytic works, belonging to the Allgemeine Elektro Metallurgische Gesellschaft at Papenburg an der Ems, Germany, are said to be producing a small output of copper and nickel, according to a modified Hoepfner process, using a chloride solution. It is stated that the capacity of the works is about 1 ton of refined copper daily, and the same quantity of electro nickel, although the actual output is certainly considerably less than this amount.

The process is applied particularly to ores and matte, these being leached with a cupric chloride solution, so as to dissolve their copper, lead, nickel and silver contents, and simultaneously reduce the cupric salt to the cuprous state. After purification and being freed from silver, the solution is passed into electrolytic cells with carbon anodes and copper cathodes. Chlorine is liberated at the anodes and utilized, and the cupric and nickelic solution remaining after electrolysis is withdrawn, freed from copper, its nickel contents recovered electrolytically, and the remaining solution re-used in leaching a fresh charge of ore or matte. Very recent reports indicate that the Papenburg concern has not yet achieved commercially successful results, that for all practical purposes Hoepfner's original process has been abandoned and that the entire plant is being remodeled.

### VI. Proposed Sault Ste. Marie Copper and Nickel Refinery.

The Consolidated Lake Superior Co. propose the erection of a large copper and nickel smelting and refining works at Sault Ste. Marie, either on the Michigan or on the Algoma side. Plans and estimates have been prepared for a plant with a daily productive capacity of 75 tons of fine copper, 7.5 tons of fine nickel and for refining the precious metals contained in the material to be treated, according to my improved process and plant. The works are designed especially for treating anodes of crude nickeliferous copper, averaging, say, 88 per cent. Cu, 8.8 per cent. Ni, and, say, 20 ozs. Ag. per ton. These nickeliferous anodes may be secured by adding a certain tonnage of Sudbury matte to at least double this quantity of Lake "mineral," slagging off the iron silicate, removing the sulphur, refining up to the desired point and finally casting the product into anodes. I would recommend the employment of Mr. Thum's electrode

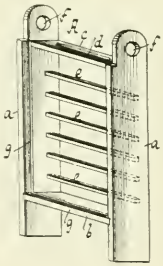



FIG. 1.

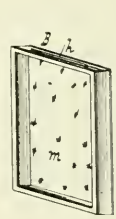



FIG. 2.

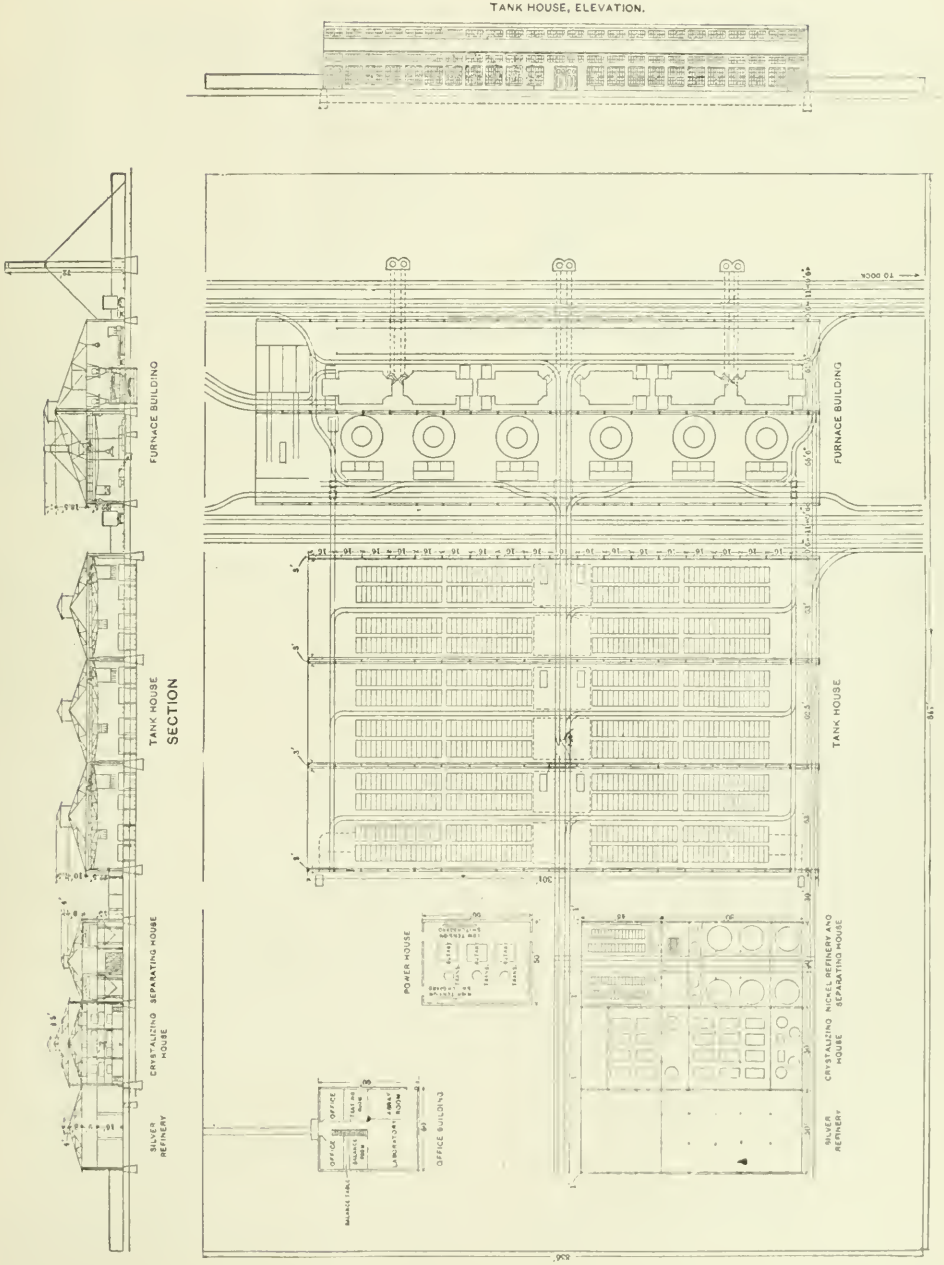
FIG. 3.

THUM'S ELECTROLYTIC APPARATUS.

frame, described later, in connection with my improved process for the separation and electro-deposition of nickel. This combination method would then embody the reduction of the nickel sulphate obtained in the second stage of my process to the granular, semi-metallic, or "reduced black-oxide" state, and the use of this material instead of lead, as an anode. The reduction of nickel sulphate or oxide with carbon to granular nickel takes place at a low temperature, while reduction and fusion to a *solid* nickel anode requires a high temperature and is therefore much more expensive than the process advocated.

The neutrality of the electrolyte must in every case be carefully maintained, for if it is not kept constantly neutral or approximately so, and is allowed to change from an acid to an alkaline reaction or *vice versa* deposition, the electro-depositing nickel is apt to peel off and cause trouble.

The apparatus for depositing nickel described in Mr. F. A. Thum's U. S. patent No. 614,633 of November 22, 1898, as applied to nickel refining, consists essentially of a non-conducting frame A and B (see Figs. 1, 2 and 4), adapted to hold the finely powdered or granular nickeliferous material to be refined, said frame being closed at the side facing the positive conductor by a removable plate of nickel or a greased sheet of copper, and at the opposite side by a diaphragm of muslin or other suitable material. A number of such frames or elements are assembled in an electrolytic tank and arranged according




DESIGN OF PROPOSED COPPER AND NICKEL REFINERY.

the series process (see Fig. 5), the positive current being conducted to the material to be refined, which serves as an anode, of the first element of the series, and the negative current taken away from the cathode plate or sheet of the last element, without the intervention of any intermediate conductors excepting the elements themselves. At the top of the frame is a charging opening for supplying the anode material. In detail, the frame A is formed of side pieces *aa*, bottom *b* with grooves *g*, top *c* with opening *d* and cross bars *ee*, while B is provided with an opening *h* at the top and is closed at the outer end by a diaphragm of muslin or other suitable material *m*. Frame B is inserted into the frame A, so that the diaphragm *m* is supported by the cross bars *ee* and the opening *h* is beneath the opening *d*. The element is completed, finally,

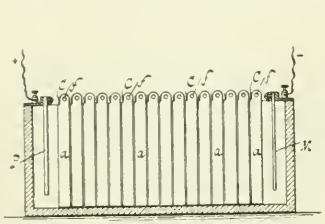


FIG. 5.

FIG. 4.

THUM'S ELECTROLYTIC APPARATUS.

by a plate C of metal, such as nickel or copper, which is slightly greased and inserted into the grooves *g*, and serves as a receiver for the deposited electrolytic nickel.

When a suitable electric current is passed through the tank, filled as it is with a hot neutral solution of nickel sulphate and the electrodes as described, the anode material is dissolved on the diaphragm side and the nickel is deposited on the opposite cathode plate. As soon as the deposit has reached a sufficient thickness, it is removed and melted into ingots, or utilized, as I prefer, without melting, as the latter process is apt to introduce injurious impurities into the nickel.

Whenever there is a settlement of the material in the casing, fresh material may be charged through the openings *d* and *h*. From time to time the elements are in rotation removed from the tank, the deposits stripped from the plates C, the residue within the casing emptied, and the casing refilled.

### CONCLUSION.

In the processes for the electro-deposition of nickel with insoluble anodes no very recent progress has been shown. When the metal is recovered on a large scale by the aid of soluble anodes, the electrolyte is kept constantly at a predetermined degree of saturation and at the point of neutrality, on which condition largely depends the nature of the deposit and the commercial success of the process. When insoluble anodes are used in refining nickel, however, an equivalent of free acid is left in the electrolyte for every equivalent of metal deposited, and in consequence the nickel deposit is apt to deteriorate, the chemical and electrical conditions of the bath are changed, polarization ensues and the resistance of the electrolyte increases. This, of course, means that the voltage and power required must be increased proportionately, and the cost of refining with insoluble anodes may thus become next to prohibitory, as compared with a similar process using soluble anodes. These and other difficulties have been the chief reasons why our electrochemists, instead of making pure metallic nickel by electrodeposition, preferred to work the nickel solutions into marketable sulphates, double sulphates and chlorides, which have had a ready sale until recently, but which now seem likely to become a drug on the market, just as copper-sulphate was before the adoption of electrolytic refining methods.

Permit me to say, in closing, that if any of the above-made suggestions will aid in improving the technical practice and commercial success of my co-workers in this interesting and fertile field of electrochemical work, the object of this paper will have been fully attained.

## NOTES ON PHYSICAL CHARACTERISTICS OF ELECTRODEPOSITED METALS.

By Woolsey McA. Johnson.

This subject has never been adequately treated in any book on electrochemistry, either theoretical or practical. We find in the literature a mass of experimental evidence, but no attempt has been made to collect it and to classify it. Consequently the explanations of the varied phenomenon are always of a special nature.

In the limits of this short article it is impossible to give any general scheme, but it was thought that an investigation of why in one case the deposit is good and in another case the deposit is poor will help others to systematize our knowledge and tell us the reason for the facts as we know them.

One of the first things observed in studying this question is that in electroplating "double salts" are often used, and usually with excellent results.

The modern theory of electrolytic dissociation has developed some remarkable facts about these double salts, or, as it calls the resultants of them, "complex ions." We know, for example, that it is possible to reverse a Daniell cell by simply adding a strong solution of KCN to the catholyte; that this will give a steady discharge of a considerable current, with the copper dissolving and the zinc being precipitated.

By Nernst's equation we have

$$E = e_1 - e_2 = 0.058 \log. \frac{Pzn}{pzn} - 0.058 \log. \frac{Pcu}{pcu}$$

neglecting the small e. m. f. at the contact of the solutions.

Now, when we add KCN to catholyte, we do not affect Pzn or pzn or Pcu, but we reduce Pcu to a small value. In other words, we have decreased the ionic pressure of copper to an amount so small that its own solution pressure is sufficient to push the copper ions continually into solution. Copper hydrate is, for analytical purposes, considered insoluble, but the solution pressure of $Cu(OH)_2$ with regard to the copper ions is large compared to that of the potassium copper-cyanide that is formed.

Similarly, we find that in a "concentration cell" that reagent which produces a chemical action in precipitating a dissolved salt or in dissolving a precipitate gives a higher e. m. f. against the standard electrode.

To be concrete, the cell

Ag|AgNO$_3$ 0.1m|AgCl nKCl|Ag gave 0. 54 volt.
Ag|AgNO$_3$ 0.1m AgNO$_3$, nNH$_4$OH|Ag gave 0.54 volt.
Ag|AgNO$_3$ 0.1m AgBr nKBr|Ag gave 0.64 volt.
Ag|AgNO$_3$ 0.1m|AgNO$_3$ Na$_2$S$_2$O$_3$|Ag gave 0.84 volt.
Ag|AgNO$_3$ 0.1m AgI KI|Ag gave 0.91 volt.
Ag|AgNO$_3$ 0.1m AgNO$_3$ KCN|Ag gave 1.31 volt.
Ag|AgNO$_3$ 0.1m AgNO$_3$ Na$_2$S|Ag gave 1.36 volt.

We can see that each reagent in the electrochemical series produces a chemical action on the compound just below it. For instance, AgCl is soluble in NH$_4$OH, while AgBr is precipitated by the action of KBr on the soluble ammoniacal silver salt. The same is seen through the series $Na_2S_2O_3$, KI, KCN, $Na_2S$. His knowledge throws a Nernst light on the subject. We find in the ionic theory of concentration cells a satisfactory explanation for the perfect correspondence between chemical behavior and the electrochemical quantity, e. m. f. against a standard electrode. The same correspondence is found true in most concentration cells measured. For further particulars, the reader is referred to Nernst's classical researches on concentration cells, in the *Zeit. f. Phys. Chemie*, 1889, or to Le Blanc's "Elements of Electrochemistry" (translated by W. R. Whitney), p. 178.

It is therefore quite easy to understand why NH$_4$OH dissolves AgCl, etc. It is that a double salt is formed by the two,

which has such a small pressure of silver ions that the reaction proceeds until equilibrium is reached. Looked at broadly, it is little different from the rising of heated air or the flowing of water down-hill. All three actions consist in matter flowing from high pressure to low pressure. The difference lies in us. Water pressure and air pressure are familiar to our minds, but an ion pressure is a new conception.

As is well known, these double salts are found useful to the electroplater. We need only instance the nickel bath of double nickel ammonium sulphate and the silver bath of the soluble potassium silver cyanide. (In electroanalysis Professor Classen has made use of the double ammonium oxalates, etc.)

The value of these double salts is connected in several ways with the formation of complex ions. In the first place, they render necessary a high voltage. Take silver plating, for example. If a solution of silver nitrate were used, we could deposit silver at a very low "electrode voltage." By using the solution of $KAg(CN)_2$, we use a voltage higher by 1.20 volts. The ions are hurled out of the solution under great pressure. The following analogy illustrates this point. To be a bit slangy, we will consider a boy throwing snow at the shingled side of a house. If he tosses it gently, it is not apt to stick, unless it is very sticky snow; but if he gets off 10 feet and "slugs" snowballs at it, the snow is pretty sure to get in between the cracks and stay there. Naturally, with a high electrode voltage, we are apt to have good, solid, adherent deposits. By this term, "electrode voltage," is not meant the voltage across the terminals of the vat, but the voltage of the electrode against a standard electrode. In other words, we measure the electromotive force with which the cations are drawn from the catholyte to the cathode. This voltage can be measured by a potentiometer if we use the hydrogen electrode, or, in case we use a electrode which will not polarize with a current of several milliampères, by a Weston voltmeter.

The necessity of distinguishing between "electrode voltage" and "terminal voltage" cannot be too strongly emphasized.

Both "terminal voltage" and current density are useful terms in their place, but they do not tell us much about the electrochemical reactions which are taking place. "Electrode voltage," or "electrode potential," to use the more correct term, is the quantity that should be measured. Suppose we are refining a copper anode carrying gold values. We find that, with a certain current density and a certain solution, we have a slime carrying 99.5 per cent. of the gold in the anode. Now, if we substituted for the copper anode a silver anode carrying the same amount of gold, we should find that quite a considerable portion of gold would be carried to the cathode. Measurement with the potentiometer against a hydrogen electrode would show the reason for the discrepancy in the difference of readings. The question of surface is a large factor. Some anodes are porous, and, on dissolution, present a larger surface to the current than measurements would indicate. Again, the current density is not uniform. The anode surface is not constant in chemical composition. It has been known for thirty odd years that the silver in copper concentrates in an outside layer. A few of these facts are mentioned to show that in electrolytic works conditions are rarely such as they are supposed at first glance, and the "electrode potentiometer" is a good instrument to use when we wish to learn bottom facts and with which to diagnose these unknown variations.

The writer was at one time employed in experimental electrorefining. It was found possible to gradually run the slimes from 4-ounce precious metals to 15-ounce, 28-ounce, 78-ounce successively. The potentiometer method of measuring the e. m. f. of the anode against the standard electrode was the best help that could be found whenever trouble arose.

The same method is of value in telling us what happens electrochemically at the cathode. The reading of potentiometer gives us exactly the relative forces which pull the cations out of the solution.

We know that it is necessary to have also a good supply of cations present in the catholyte, as well as to have a high "electrode voltage" of deposition. If a single salt were used, we should be obliged to use a concentrated solution to attain this condition. To use a high electrode potential in depositing, we should be obliged to use with a single salt a high current density. This would mean that the catholyte would be quickly impoverished of cations. In accordance with these facts, we find that all successful processes for making springy and elastic electro copper in sheets use fairly high current density, strong solutions and keep the catholyte constant by some means of circulation. Just here is where the double salt, with its complex ion, plays an important *rôle*. It causes a high e. m. f. to be used in depositing, and it furnishes the catholyte with a good supply of cations by its continuous decomposition. A good electrodeposit is therefore obtained from the double salt for good electrochemical reasons.

The function of the double salt, in preserving a fairly constant cation concentration, is in line with the importance of concentration changes, as shown in the working of the lead accumulator.

The solution which has undergone electrolysis undergoes often permanent chemical changes, forming basic insoluble salts. These salts are either held partly or entirely in solution by the double salt.

In storage-battery work it is found that the bottom of a plate ages faster than the top of the plate. Analyze the top layer of the electrolyte and the bottom layer, and it will be found that the bottom becomes concentrated and the top dilute. This makes a non-uniform current density, and causes thereby lowered efficiency, because of local action of the vertical "concentration cell" set up.

In electrodeposition we use much higher current density and we have a soluble anode, while in the lead accumulator both electrodes gain in weight on discharge and lose in weight on charge. The action of a soluble anode is partly reversible, as in the lead accumulator. The irreversibility depends largely on these concentration changes. To counteract these changes and to keep the electrolyte of uniform composition is the function of the numerous devices for circulating the electrolyte, by blowing air through it, forcing the solution in a jet at the cathode or by moving the cathode, etc. A good part of the advantage found in hot solutions is due to the fact that they necessitate some circulation.

The effect of these concentration changes on the character of the bath is often permanent, as remarked above. If we use a high current density in electrolyzing the nickel bath, we have the formation of nickelic sulphate in the anolyte, and of nickelous hydroxide or basic sulphate in the catholyte. These last two compounds are, of course, insoluble in neutral solutions, and very slowly soluble in dilute acid solutions. They form a slime which renders the solution turbid, falls to the bottom of the vat, or, in extreme cases, will form a thick apple green paint on the cathode.

By the electrochemical reaction above described the electrolyte becomes acid, and we have a "gasing" at the cathode, as the velocity of counter reaction is slow. In the old Balbach nickel refining process this sludge used to collect in the "well." By stirring this sludge with electrolyte which had grown acid, the solution was kept near the neutral point. Similar phenomena have been observed by the writer in electrolyzing iron or ferro-nickel. In one case a beautiful, dull, silver white deposit will be obtained, while on a slight increase in current density the solution will have an insoluble sludge of dirty brown basic salt. The change is a very sharp one.

The formation of a cloudy precipitate or the presence of suspended particles of any kind from anode slime has, as is well known, a bad effect on the physical characteristics of electrodeposited metals. These particles have in few cases a conductivity exactly equal to that of the deposited metal, and, of course, in the case of basic salts are insulators. When adhering, as they often do, to the cathode, they cause a local distortion of the electrochemical field. The lines of force are hunted round this particle and build up the deposit at the

outer edge with great rapidity as the current density is large there. These nodules, if allowed to grow, grow *"ipso facto"* with great rapidity and spoil the deposit, making it porous and brittle, and in the case of thick deposits "warty" and poor. A hydrogen bubble will cause the same trouble. The solution can be kept clear of these suspended particles by running through a filter or filter press, or allowing to settle in outside vat.

The use of a hot solution is bad, in that it accelerates the formation of these basic salts. For nickel, the use of a hot solution is often recommended, and this fact has been known for years. In fact, a Bristol, Conn., plater was using it practically in 1888. The work of Foerster showed that for depositing thick sheets the hot (50° to 60° C.) solution was desirable. Since Foerster's work it is often stated that it is impossible to deposit a thick coating of nickel from a cold solution. Perhaps the best piece of deposited nickel the writer has every seen was on the wires suspending a plater's basket. It was three-quarters of an inch thick, hard as steel and shone with a dull silver finish. A small current density was used, and this was the cause of the excellence of the deposit. This deposit was made from a cold solution.

The reason why electrodeposited nickel "curls up" (which is said to be prevented by hot solutions, but is only prevented in certain cases) is due, in the opinion of the writer, to the tremendous molecular strain under which nickel, or rather the nickel-hydrogen alloy, is deposited. We can obtain some idea of this by the fact that the electrodeposited nickel is electropositive to cast nickel by 0.25 to 0.05 volt, according to the potential at which it was deposited. This shows that the molecules are placed under an abnormal strain. Another bit of evidence proves this physically.

Nickel was electrodeposited on a malleable nickel cathode sheet, 18 x 12 inches, which fitted in a groove in the end vat, which was 12¼ inches wide. The groove was made of slats, ½ x ½ inch in cross section, nailed to the vat and painted with asphalt paint. The surface exposed was about 18 x 11⅛ inches. At the end of six days' deposit out of a hot solution, the electrolytic sheet, still adhering to the soft sheet, was wedged in so strongly that two men were required to pull it out. The whole sheet was now elastic. In addition to the potential energy of electrolytic solution, as measured by the potentiometer, there was also the potential energy of an elastic body under strain.

Now, it will be found that both these physical quantities diminish with time, and also with temperature. Take pure electrolytic nickel (by electrolytic nickel, of course, is meant nickel alloyed with an amount of hydrogen) and anneal it in a Bunsen flame. It loses both its elasticity and its "overvoltage." Allow it to stand, and it will gradually lose these same properties.

The "curling up" of electrolytic nickel is probably caused by the fact that there is an unequal strain between the inside and outside layer. The inside layer, when deposited, had the same abnormal strain, but with time this tension has become more normal by a slow annealing action. The outside layer has had, however, no time for the molecules to adjust themselves, and consequently the tension is greater on the outside than on the inside. Electrodeposited nickel tears itself from the cathode and curls up, just as a piece of paper curls up in drying, which is undoubtedly due to unequal strains of the inside and outside layers. The curling is always such that the outside layer is on the concave side of the bending.

It is also a fact that the contact to the original cathode will determine to a large extent whether the electrolytic nickel curls or not. For instance, if the plating be on a rough or matted surface, it will stick to this cathode when it would not stick to a smooth cathode. Nickel will stick to a clean, smooth surface when it will curl from the same surface which is oiled or graphitized. When a large current density is used, nickel will often stick to the sheet, but the whole plate will curl up unless the deposit be on both sides. If the current be interrupted for a short time and then continued, the nickel deposit will in many cases curl up where film of oxide, formed during interruption, has made a plane of weakness. Further facts could be adduced to point to the same conclusion—that the curling up of electrodeposited nickel is due to the unequal strains between outside and inside layers, and that hot solutions and low electrode voltage, which have been found to be favorable, are favorable because they tend to equalize these strains.

In conclusion it may be said that there are few better fields for investigation than that indicated in the title of this article. If such divigations as these lead anyone to explore this field thoroughly, the writer will feel more than repaid for putting his modest views before the electrochemical world.

Sidney, C. B., January 28th.

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## PIONEERS OF ELECTROCHEMISTRY—V.

### Wilhelm Ostwald.

In one of his lectures on "Physical Chemistry," held at the celebration of the tenth anniversary of the University of Chicago, J. H. van't Hoff, while reviewing the historical development of physical chemistry, makes the following remark: "It is a rather small number of those who, working not always under the most favorable conditions, have contributed during the last fifteen years to the development of physical chemistry. Ostwald must be mentioned first, who, by his comprehensive activity as a teacher, by his surprising literary work, and by his talent as an organizer, has probably done more for the development of physical chemistry than many others."

A good deal of the work of Prof. Ostwald has had to do with electrochemistry, and he was indeed a directing force in the development of modern theoretical electrochemistry on the basis of the so-called theory of electrolytic dissociation. Even those who think that here too large a building was erected on too narrow a basis have never denied the "inspiring atmosphere of Ostwald's laboratory," and there is nobody who would not admit that Ostwald's work has done a great amount of good in stimulating and directing researches which are certain to bring fruits in the further development of electrochemical science and industry. It is thus highly appropriate that his name should be placed here among the pioneers of electrochemistry.

Wilhelm Ostwald was born in Riga, Russia, on August 21 (September 2d), 1853, as the son of a cooper. After having passed through a grammar school, he visited the Realgymnasium at Riga, from which he was graduated in 1871. As a boy he was mechanically inclined and his father wanted him to become an engineer, and was somewhat sorry that his son insisted on a purely scientific career. In January, 1872, he entered the University of Dorpat and studied for three years chemistry and physics, his most adored professors being C. Schmidt, A. von Oettingen, and Joh. Lemberg. In 1875 he became assistant in the physical laboratory of the university.

In the same year (1875) he published his first investigation on the mass action of water (*Jour. f. Prakt. Chemie*). In 1876 he published in the same journal a paper on volumetric chemical studies. The same subject was dealt with in the thesis for his master's degree (1877), and in the thesis for the degree of doctor of philosophy (1878). In 1878 he began his work as a university teacher by lecturing, two hours a week, on the theory of chemical affinity.

In the following years he published quite a series of papers on the subject of chemical affinity. Having been assistant in the chemical laboratory since 1875, he became in 1880 assistant in the physical laboratory. In the same year he married.

In the autumn of 1881, Ostwald became professor of chemistry in the Institute of Technology of Riga, the city of his birth. Here he remained for six years, and in this period his

Lehrbuch der Allgemeinen Chemie" was written (1883 to 1886). Shortly after this well known work had been finished, he, in conjunction with Prof. van't Hoff, founded in the spring of 1887 the *Zeitschrift f. Physikalische Chemie*.

In the autumn of 1887, Ostwald was called to the University of Leipzig, where he still remains as professor of chemistry, in special charge of the branch of physical chemistry. It was here that he developed his enormous activity.

Besides his papers published in various journals, but mainly in the *Zeitschrift f. Phys. Chemie*, Ostwald has written the following books: "Grundriss der Allgemeinen Chemie" (1889, 1890, 1899); "Lehrbuch" (1883-89, 1891); "Hand-und Hilfsbuch" (1893, 1902); "Geschichte der Elektrochemie" (1894-95); "Wissenschaftliche Grundlagen der Analytischen Chemie" (1894, 1897, 1901); "Aeltere Geschichte der Lehre von den Berührungswirkungen" (1898); "Grundlinen der Anorganischen Chemie" (1900).

In 1901 Ostwald founded the *Annalen f. Naturphilosophie*. Since 1883 he is the editor of the well-known series "Klassiker der Exakten Wissenschaften." In 1892 he published a German translation of Gibbs' fundamental thermodynamical papers. These papers, buried before in scarcely accessible transactions, became thus accessible to the general scientific public, and the German Ostwald was thus instrumental in making known the name of the greatest thermodynamical scientist of the United States. In 1897 and 1898 a new laboratory was built, according to the suggestion of Ostwald. The enormous work, done by his students in the old laboratory under his direction, and according to his suggestions, may be appreciated from the collection of their papers in four volumes.

In 1893 Ostwald founded the German Electrochemical Society. He was its recognized soul and heart, and to him is also due the recent change of the name into German Bunsen Society, which name was chosen to indicate the broader scope of physical chemistry in general.

In spite of his pronounced scientific progressiveness, Professor Ostwald possesses that conservative spirit which is achieved by the historical study of the development of science. Although firmly fixed in his scientific convictions, he is no fanatic. In the German Electrochemical Society he always advocated the co-operation of theorists and practical men. The number of his old students is legion; they are found wherever physical chemistry and electrochemistry are taught or applied, in universities and schools, as well as in the laboratories of chemical manufacturers, not only in Germany, but all over the world.

May Geheimrat Ostwald continue his fruitful activity for many years to come.

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl.

APPARATUS AND PROCESSES FOR THE ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

*Manufacture of Chlorates.* R. Threlfall, Birmingham, England. Patent No. 710,780, December 23, 1902. Application filed May 2, 1902.

The inventor claims to have discovered that in order to obtain a high current efficiency in the manufacture of chlorates it is necessary to have a certain amount of free hypochlorous acid always present in the electrolyte, preferably about two grams HClO per liter. He proposes to obtain this by splitting off a part of the electrolyzing current and diverting it to an auxiliary cathode, arranged in a suitable porous vessel, either inside or outside the main electrolytic vat. There is thus more chlorine formed at the main anode than alkali at the main cathode, and the excess of chlorine at the anode is said to react with the hypochloride present in the electrolyte, according to the equation $RClO + H_2O + 2Cl = RCl + HClO_3$, R designating one atom of an alkali metal. HClO spontaneously breaks up as follows: $3HClO = 2HCl + HClO_3$ and $HClO + RClO = RCl + HClO_3$, the two reactions being continuously repeated. Electrolysis in the main vessel takes place without a diaphragm; the anode is preferably made of platinum or platinum alloys, and the cathode either of the same materials or of carbon. A regulating resistance is arranged in the path of the current to the auxiliary cathode, in order to stop or vary the action. With a current of 1,000 ampères, about 950 amperes pass to the main cathode and the remaining 50 amperes to the auxiliary cathode. Approximately 90 per cent. of the theoretical yield of chlorate is said to be obtainable by this process.

*Apparatus for Producing Caustic Soda by Electrolysis.* E. A. Allen, Rumford Falls, Me., and H. K. Moore, Lynn, Mass. Patent No. 710,804, December 23, 1902. Application filed December 27, 1898.

Fig. 1 shows a cross section of the apparatus. The underlying principle of its construction is the same as the Hargreaves apparatus, namely, the arrangement of the cathode on the outside of a diaphragm, and not in direct contact with the electrolyte. The cell has two end walls, connected at their upper ends by two bars $a^4$ $a^4$, thus leaving the longitudinal sides entirely open. The open sides are closed by a diaphragm *b* of asbestos paper or other substance, which will permit the free percolation of the electrolyte. On the outside of each diaphragm is arranged the cathode *c*, consisting of a series of layers of wire cloth or a bed of steel wool, in the form of a

comparatively thick sponge. The asbestos paper and the wire sponge are bent under the bottom plate, in order to make electrical contact with the long iron plate *d*, upon which the cells rest side by side. The anode consists of pieces of gas carbon *c* cast in a lead frame *c*¹. A sheet lead jacket *f* dips into a groove *a*¹, filled with any suitable non-volatile hydrocarbon, such as coal tar, to form a seal for the chlorine. Suitable openings, capped by a glass dome *g*, are left in the cover of the cell to conduct the chlorine away. The plate *d*, which is connected with the source of the current, is inclined and provided with a trough at its lower edge, in order to receive the fluid resulting from the electrolysis. During electrolysis the solution percolating through the diaphragm trickles down through the cathode sponge from top to bottom, being constantly exposed to the action of the current on its way down, with the result that it reaches the plate *d* in the consistency of molasses and consists of caustic soda with only a small percentage of sodium chloride. It is stated that a current density of not less than 444 nor over 510 ampères per square meter of cathode surface produces the best results, and the diaphragm should preferably be made to permit a percolation of about 3 liters to each square meter of diaphragm surface in one hour. The temperature of the cell should not be increased above 80° C.

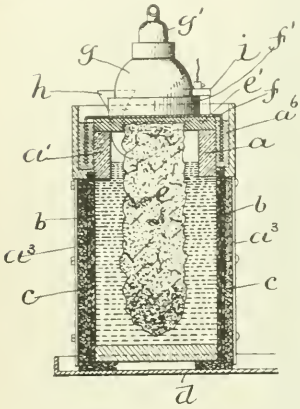


FIG. 1.—CAUSTIC SODA APPARATUS.

*Electrolytic Apparatus.* Max Haas, Ane, Germany. Patent No. 718,249, January 13, 1903. Application filed August 6, 1901.

The apparatus is an improvement on the well-known Haas and Oettel apparatus for the production of bleaching solutions. It aims at overcoming the loss of current incident upon the use of bipolar electrodes, and arising from the fact that the electrolyte itself forms a connection between the various compartments of an apparatus. In the present construction long, narrow tubes of non-conducting material are provided, through which the electrolyte has to flow in order to pass from one compartment into the other or from the storage reservoir into the various compartments, and thence to the collecting vessel. The idea is to oppose so much resistance to the current by the long pipe connection that it will be so much greater than the resistance within the compartments that practically all the current will flow through the compartments, and the loss become so small that it practically does not come into consideration. The bipolar electrodes are made of carbon, as in the older form of the Haas and Oettel apparatus. Motion of the electrolyte is brought about by the ascending bubbles of hydrogen, in substantially the same manner as in the German patents by the above inventors.

*Deposition of Metals on Earthenware Articles.* G. W. Layhourn, Hoke-upon-Trent, England. Patent No. 716,559, December 23, 1902. Application filed June 17, 1902.

The invention relates to the deposition of metals or metallic coatings on domestic, ornamental, sanitary and other earthenware articles, and its chief object is to deposit the metals after the articles have been specially prepared and brought to a highly porous condition. It is claimed that the conductivity of the water in which the articles are steeped before they are placed in the electroplating bath, and which fills the pores, greatly assists the deposition of the metals.

### Storage Batteries.

*Storage Battery.* C. H. Clare, Quincy, Mass. Patent No. 717,351, December 30, 1902. Application filed March 1, 1902.

The invention relates to storage batteries in which the active material is held upon the face of the lead plates by separating plates of insulating material, and is intended to overcome the tendency of the active material to fall out from between the plates. For this purpose the inventor arranges so-called "units," groups of electrodes, held rigidly together by plates of insulating material, such as glass, gutta percha, etc., on the four sides and on the bottom. Such a unit consists, in the order named, of an insulating plate, a lead plate, a layer of active material, two porous earthenware plates with openings between them for the circulation of the electrolyte, another layer of active material, a lead plate, another layer of active material, two porous plates with openings as before, a layer of active material, a lead plate and finally another insulating plate. An insulating plate at each end and one on the bottom complete the "unit," which is rigidly bound together by two "suitable" binders, the nature of which is not given. The porous earthenware plates serve also the purpose of pressing the active material against the surface of the lead plates. The two outer lead plates are connected together to form one electrode, while the inner lead plate forms the other electrode.

*Secondary Battery.* I. Kitsee, Philadelphia, Pa. Patent No. 717,416, December 30, 1902. Application filed April 10, 1893.

Application for this patent was filed nearly ten years ago, and a whole host of patents have since been taken out in this country and abroad with the same object in view, namely, to prevent the buckling of the electrodes by providing for the expansion of the active material. The electrode in this construction consists of a rectangular frame of conducting material, presumably lead, in which is placed a band of conducting material bent into zig-zag form, so as to form spaces, which are to be filled with active material. Soft rubber bands are then placed around the electrode thus formed, and a perforated sheet of non-conducting material is placed on each side. In order to keep these sheets in position, a second series of rubber bands is placed around the whole. The active material is provided with holes to allow for the circulation of the electrolyte. The conducting band is bent in such a manner as to allow room for the expansion of the active material.

*Secondary Battery.* W. Morrison, Chicago, Ill. Patent No. 717,107, December 30, 1902. Application filed May 19, 1900.

The inventor says: "To form the red lead into a paste, it is usually mixed with dilute sulphuric acid. This produces a small quantity of sulphate of lead, and in drying the sulphate of lead slowly sets into the mass as it hardens. With this construction, however, when the charging is carried too far, the lead sulphate is changed to a peroxide of lead, the sulphuric acid is expelled and the bond is relaxed until the peroxide coating powders and crumbles away. The object of the present invention is to overcome this difficulty, and this I have discovered may be accomplished by using hydrofluoric acid, by mixing it with the lead paste forming the active material. Hydrofluoric acid being strongly electropositive, it will unite with the sulphuric acid of the electrolyte to form a fluoride of lead, which resists the seductive effects of overcharging and perpetuates the bond of the paste, so as to prevent the latter from crumbling."

*Secondary Battery.* W. Morrison, Chicago, Ill. Patent No. 717,108, December 30, 1902. Application filed August 5, 1901.

In this patent the inventor states that the same result as

described above may be obtained by using fluorine or hydrofluoric acid or fluoride of lead or ammonia, or other compounds of lead, to be mixed with the electrolytic solution of the battery.

*Process of Preparing Storage Battery Plates.* R. C. Browne and F. Balch, Salem, Mass. Patent No. 710,603, December 23, 1902. Application filed April 21, 1902.

The inventors claim to have discovered a new process for preparing storage-battery plates prior to their formation. The following procedure, as described by them, is stated to have given the most satisfactory results, though they do not confine themselves to the exact proportions or temperatures, which may be varied to some extent: "To 30 ounces of sulphuric acid, at a temperature of 20° F., preferably contained in an open vessel or beaker, we add 17 ounces of potassium nitrate, and allow the temperature of the mixture to fall to 185° F. We then add 15 ounces of water and stir in 1½ ounces of ammonium sulphate, and when red fumes are given off we add 74 ounces more of water and allow the solution to cool to 70° F., at which temperature it is maintained while the plates are being treated. In our experience plates of lead immersed in the above-described solution and allowed to remain but three hours, while the temperature is maintained at 70° F., become heavily incrusted with scale in many superimposed layers, clinging together and of a porous nature, with a distinct grain . . . When the incrustation or coating of lead has been perfected in the solution, the plates are ready for forming by electrolysis." The inventors state that, as nearly as they have been able to ascertain, the scale is a lead sulphate, but they are led to believe by certain characteristics of it that a metallic salt is combined with the sulphate of lead, which hardens the latter and renders it more adherent.

*Storage Battery and Method of Preparing Electrodes Therefor.* L. Paget, New York City. Patent No. 717,610, January 6, 1903. Application filed January 10, 1900.

The specification describes a new form of electrode, made up of successive layers of spongy lead compressed to the density of sheet lead, 11.4 or thereabouts. Direct pressure—that is, the pressure of a press as distinguished from that of rolls—is necessary, and a pressure of from 2 to 3 tons is sufficient. The specific gravity of the compressed plates must not fall below ten, which involves loss of durability. If the specific gravity is less than about nine and one-half, the plates will be entirely unsuitable. An important feature of the invention is that the plates are built up of successive thin films, each not more than about two-hundredths of an inch in thickness. The spongy lead is applied on opposite sides of the element for successive compressions, with the result that the density of the layers will increase from the surface inward, and the plate will thus resemble a Planté plate. The thickness of the finished electrodes is stated to be about a quarter of an inch.

*Storage-Battery Electrode.* L. Paget, New York City. Patent No. 717,609, January 6, 1903. Application filed January 10, 1900.

This specification claims the electrode formed by the process outlined in the preceding patent of the same inventor.

*Method of Preparing Storage Battery Electrodes.* L. Paget, New York City. Patent No. 717,608, January 6, 1903. Application filed October 19, 1899.

*Electrode for Storage Batteries.* L. Paget, New York City. Patent No. 717,607, January 6, 1903. Application filed September 8, 1899.

These two inventions relate to a new form of storage-battery electrode and the process of preparing it. The construction of the electrode is illustrated in the accompany Fig. 2. It is formed of a series of small plates A, connected by lugs C to a common conductor B. Each of the small plates consists of a thin sheet, formed by compressing precipitated lead, and is provided with vertical corrugations. An elastic frame D of vulcanized rubber incloses the plates on the bottom and the sides. This construction permits the plates to expand and contract transversely to the corrugations during the process of charging and discharging. Each of the plates A is preferably not over an inch in width, and the thickness of them—that is, the depth of the corrugations and of the frame D—is from a quarter to a third of an inch. The sheets of lead, corrugated to form the plates, are preferably not more than one-half to one millimeter in thickness.

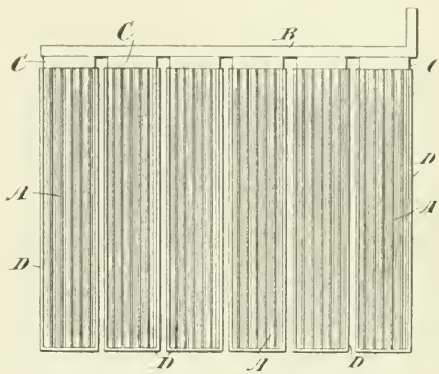



FIG. 2.—STORAGE BATTERY ELECTRODE.

*Electrical Storage Battery.* H. K. P. Barham, Portsmouth, England. Patent No. 718,045, January 6, 1903. Application filed December 2, 1901.

The battery is constructed out of a number of strips of sheet lead, arranged one above the other. Each strip is formed like a tray in its middle portion, with folded extensions at both ends. Between all the contiguous surfaces of the folding extensions and the trays are interposed sheets of absorbent or porous material, such as blotting paper, unsized paper, asbestos, etc. The absorbent sheets are saturated with an electrolyte, preferably dilute sulphuric acid.

*Secondary Battery.* J. W. Madigin, Toronto, Canada. Patent No. 718,489, January 13, 1903. Application filed February 5, 1902.

This battery, as shown by Fig. 3 in cross section, consists of a glass or rubber cell A, in which are arranged four electrodes B, B, B and C. The electrodes are separated from each other by rectangular plates or sheets F of fiber, cellulose or wood fiber, which is chemically treated with a neutral salt. The separating plates are porous, and consequently the electrolyte,

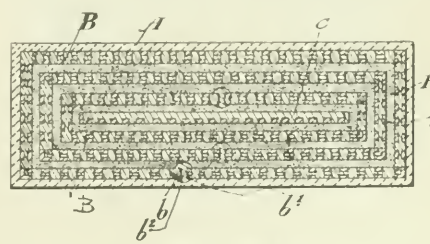



FIG. 3.—STORAGE BATTERY.

by capillary attraction, is drawn up from the bottom of the cell. The electrodes B are rectangular in form, and are constructed from a single sheet of metal folded at *b* and having its free ends at *b'*. The folded end *b* and the free ends *b'* are burnt together into the groove *br*. In this way a double plate is formed, leaving a space between, which is filled with active material. The plates are perforated in order to insure circula-

tion of the electrolyte. The inner plate C is formed with horizontal corrugations, and the space between the corrugations is filled with active material.

*Electric Battery.* M. R. Hutchinson, Upper Montclair, N. J. Patent No. 718,205, January 13, 1903. Application filed April 8, 1902.

This invention relates to electric batteries, both primary and secondary, and especially to the "dry" or "semi-dry" class. The inventor states that, as such cells generally contain a free space for the electrolyte at the top, it has been found in practice, when they are replenished, that the generated gases force the liquid out of the vent hole, which is very objectionable, especially if the cell is carried upon the person. In order to overcome this, he arranges the space for the electrolyte at the bottom or at the side of the cell, providing them with a liquid-tight plug, through which liquid can be poured into the cell after turning it upside down. When filled, the plugs are replaced and the cell turned right side up. The porous material interposed between the electrodes reaches down into the reservoir for the electrolyte, and by capillary attraction draws the liquid up.

*Battery Installation.* S. Lake, Bridgeport, Conn. Patent No. 716,844, December 23, 1902. Application filed and divided June 23, 1902.

"The present invention has for its object to prevent the escape from the storage-battery compartment of a submarine boat into the living quarters of the fumes or gases commonly set free from the battery fluid in the charging of batteries, and also to maintain the atmospheric pressure in such compartment substantially uniform and at a pre-determined tension, in order to prevent the rising of such pressure above a dangerous limit." Mechanical arrangements for accomplishing these objects are described in detail in the specification.

### Galvanic Cells.

*Electric Battery.* H. Halsey, New York City. Patent No. 717,394, December 30, 1902. Application filed April 18, 1902.

"This invention," says the inventor, "relates to that class of primary batteries invented by me in which one or both elements, wholly submerged, are revolved during the operation of the battery. . . . I employ in a battery a movable element and means for moving said element at any desirable rate of speed, and, inasmuch as the output of the battery will vary proportionately to the difference in speed between the element and the electrolyte, the output of the battery may be varied by varying the speed of the element. To maintain the constancy of the output, I provide means for keeping the surfaces of the elements clean." The cell shows a movable and a stationary electrode, the movable electrode being rotated by an electric motor run by current furnished by the cell itself. The revolving electrode carries brushes which rub against the surface of the stationary electrode for the purpose of keeping it clean and preventing polarization. Provision is also made for introducing depolarizing agents, such as bichromate of potassium. The mode of operation is described as follows: "The initial output of the battery is always sufficient to start the motor, and thus revolve the movable element. If the element remains stationary, the output of the battery will be first at its maximum, but as polarization increases the output will proportionately decrease; but, as the initial current from the battery starts the revolution of the element or electrolyte, the output of the battery will remain at maximum if the speed of the element or electrolyte be also maintained at its maximum." The idea of having to buy a motor with every galvanic cell is certainly a novel one, but it is doubtful whether it will find much favor with the general public.

*Electric Battery.* H. Halsey, New York City. Patent No. 717,395, December 30, 1902. Application filed April 18, 1902.

This invention covers substantially the same ground as the preceding, showing only a different mechanical arrangement for effecting depolarization of the electrodes. The motor for driving the movable electrode is again very much in evidence.

*Battery.* Louis Begeman, Cedar Falls, Iowa. Patent No. 718,076, January 13, 1903. Application filed January 7, 1902.

The construction is intended to be an improvement on the Lalande type of battery, in which the positive pole is formed of any suitable metal surrounded or covered by oxide of copper, which acts as depolarizing agent, the negative pole by zinc and caustic soda or potash used as electrolyte. The containing vessel, of tin, copper or iron, is corrugated, and the depolarizing agent, copper oxide, is supported in these corrugations. In order to keep the copper oxide in place, the vessel is lined with wire gauze, which in turn is covered by a shield of muslin or similar material to guard against any particles of the oxide falling through. This material is again supported by inner lining of wire gauze or netting, preferably of elastic metal. The zinc electrode is formed in the shape of a hollow cylinder.

*Electric Battery.* Georges Rosset, Paris, France. Patent No. 716,762, December 23, 1902. Application filed February 20, 1901.

The inventor proposes a new depolarizing agent, namely, the cuprates of the alkalies, and especially the cuprate of ammonia. The depolarizing agent may be obtained by introducing concentrated ammonia solution or ammonia gas into a concentrated solution of sulphate of copper and re-dissolving the precipitate in an excess of ammonia. The same procedure may be followed in order to produce the cuprates of potassium or sodium, only the excess of alkali intended to re-dissolve the precipitate is added in the presence of an organic substance, such as glycerine or tartaric acid. In order to avoid diffusion of the depolarizing agent, the inventor makes use of a porous vessel, in the pores of which he deposits a membrane of ferrocyanide of copper by substantially the same procedure as is familiar from the description of Pfeffer's osmotic experiments. A plate of carbon, forming the positive electrode, is placed in the porous vessel, the vessel filled with a concentrated solution of cuprate of ammonia and placed into an outer vessel containing a concentrated solution of sal-ammonia and a zinc rod as negative electrode. The action of the depolarizer is explained as follows: "Polarizing hydrogen appears at the carbon electrode, and reduces the cuprate solution to cuprite, but stops at this stage, because the reduction of cuprate to cuprite requires less work than the reduction of cuprite to metallic copper. The diffusion currents, aided by the lightness of the freed ammonia, bring this cuprite to the surface of the cell, where the oxygen of the atmosphere converts it back into cuprate, which, being denser, sinks back. During the operation the depolarizing agent consists of a mixture of cuprate, cuprite, deposited copper sometimes, and dissolved free ammonia; and this mixture, by self-regeneration, due to oxidation in the atmosphere, yields finally cuprate of ammonia."

*Electric-Battery Compound.* G. Bastedo, Brooklyn, N. Y.

This compound is intended for use in forming lead peroxide on the positive pole electrode in a lead and zinc battery, and consists of dilute sulphuric acid, 15 pounds; nitric acid, 50 grams; bisulphate of mercury, 1 ounce. The nitric acid and bisulphate of mercury are first thoroughly mixed, then the dilute sulphuric acid is added, and the whole thoroughly mixed again, when the compound is ready for use.

*Diaphragm for Batteries.* F. A. Decker and W. P. Divine, Philadelphia, Pa. Patent No. 717,549, January 6, 1903. Application filed April 9, 1902.

The diaphragm is made of clay, molded and baked, with reinforcing ribs and raised edges. The inventors claim to have found that the efficiency is greatly increased and the resistance greatly reduced by molding and baking the diaphragms of greater thickness than required, and then reducing the surfaces, with the exception of the reinforced portions, by

grinding or sand-blasting until a thin body of porous character is produced. Carbon diaphragms may be substituted for those of clay.

## MISCELLANEOUS.

*Process of Coating Phonograph Records.* T. A. Edison, Llewellyn Park, N. J. Patent No. 713,863, November 18, 1902. Application filed June 16, 1900.

In this specification T. A. Edison discloses a new method for coating phonograph records. Formerly he accomplished this object by causing the formation of an electric arc between two bodies of the metal of which the deposit was to be made

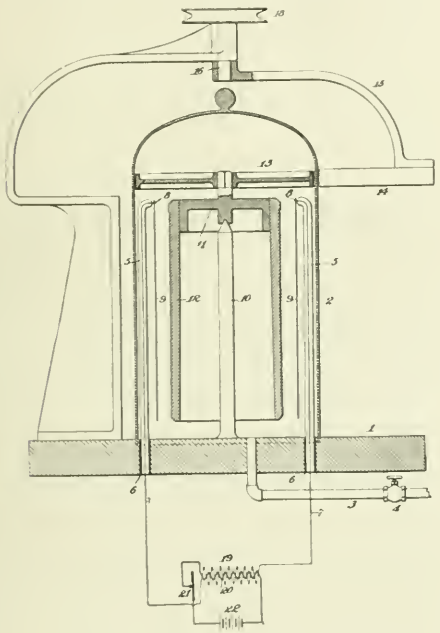


FIG. 4.—PHONOGRAPH RECORD APPARATUS.

in a vacuum, but it has been discovered that the rapidity of the process is increased and the disadvantages, such as injuring the delicate material by the heat of the arc, are avoided by the use of a silent discharge of electricity at high tension. Such a silent discharge may be produced from an induction coil of large capacity, or from a Helmholtz induction machine. The creation of a silent, or practically silent, discharge between two electrodes results in the vaporization of the metal, and the metallic vapors are carried directly toward and upon the record to be coated. The precipitation takes place most uniformly when the record is rotated, and, as the proper vaporization of the metal is only carried on in the presence of a high vacuum, the rotation is accomplished by a magnet outside the vacuum chamber. Fig. 4 illustrates the apparatus. A vacuum chamber 2 rests upon a base 1, and an exhaust pipe 3, to which an air pump or Sprengel pump can be attached, leads to the interior of the jar; 5, 5 are two supporting arms, preferably of glass, insulated from the base by hard rubber rings 6, into each of which a conductor 7 is introduced, with a hook 8 at its upper end. From each hook is suspended a strip or foil 9 of the metal, preferably gold, with which the record is to be coated, which strips serve as electrodes. A standard 10 mounted between the electrodes carries a rotating head 11, in which is supported a phonograph record 12. An iron or steel armature 13 is adapted to be rotated by a magnet 14, supported by arm 15 from shaft 16, carried by bracket 17 and rotated by pulley 18. In operation, the conductors 7, 7 are connected with the secondary of a large induction coil 19; the record is rotated, and the metal vaporized by the discharge is deposited upon it in an infinitesimally thin film. After that the cylinder is removed to a plating bath, where it receives a heavier deposit; and then the original record is removed, either by melting it out or by shrinking it from the deposited metal, leaving an absolutely accurate matrix of the original record.

*Apparatus for Purifying Water.* H. M. Livor, New York City. Patent No. 718,485, January 13, 1903. Application filed March 7, 1902.

The apparatus is shown in the accompanying illustration, Fig. 5, in which A represents a containing vessel for the purified water, made preferably of insulating material. F is a vessel containing an interior filtering chamber F', the lower end of which is provided with a cylindrical wire gauze or netting G, filled with sand M. O is a connection between filter and supply chamber. The electrolysis of the water takes place in vessel B, which is constructed of insulating material, and has at its bottom a flange, with which it fits into vessel A. A closely-fitting metallic ring E', made preferably of aluminium, constitutes one electrode. The other electrode, arranged concentric to the first, consists of an aluminium cylinder C. L, L are brackets on the inner surface of the electrode C, upon which rests an insulating disk H, supporting a strong spiral spring S, the upper end of which bears against a similar disk H' secured to the bottom of the metallic water-supply chamber E, which rests normally with its bottom on the cylindrical electrode C, thus making good electrical contact therewith; *b* and *b'* are binding posts connected with the respective electrodes. In operation, the water flows from chamber E through cock I and tube J into the annular space between the electrodes. There it is subjected to the action of the current and overflows through P and the tube H into the filtering vessel F, then upward through the wire gauze G and sand filter M through

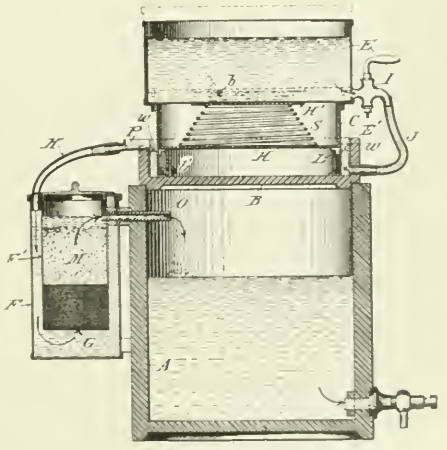


FIG. 5.—APPARATUS FOR PURIFYING WATER.

the pipe O into the container A. When the level of the water falls too low in vessel E, the spring S comes into action and lifts the vessel into the position shown in dotted lines, thus interrupting the contact between vessel E and the electrode C. The apparatus can be quickly disconnected, and the filter easily taken out and cleaned.

*Process of Electrolytically Preparing Metals and Alloys for Lithographic Purposes.* O. C. Strecker, Cologne, Germany. Patent No. 710,309, December 16, 1902. Application filed April 19, 1900.

The inventor claims: "The process for preparing metal

plate and alloys for lithographic printing, consisting in preparing the plate by preliminary grinding, rinsing, subjecting to an acidulated watery solution, washing and drying, fixing the negative upon the surface thus prepared, coating with gum arabic, treating with lithophane after the gum arabic has tried to dissolve the greasy substance, washing the plate with water to free it from the gum arabic, dusting with powdered colophane and rubbing this off, then submitting the plate as an electrode to electrolytic action in a solution of salts and gum arabic." The plate is used as anode in an electrolyte composed of a solution of 2.5 per cent. of fluoride of sodium. The density of the current is 0.5 to 0.9 ampères per square foot, and the action may last from two to five minutes. Zinc plates are preferred, on account of the cheapness of the material and the exceedingly good results obtained. An alternating current may also be used, in which case the electrolyte will be a solution of borax neutralized with boric acid 2 per cent. strong. By using this method, the current oxidizes the plate to ZnO, which is then treated with a weak solution of acid, preferably phosphoric acid. In special cases an electrolyte of a mixture of 3 ounces of ammonium silico fluoride, 3 ounces of ammonium nitrate and 3 ounces of gum arabic in $1^1/_2$ pints of water is employed.

## LORD KELVIN AND GEORGE WESTINGHOUSE.

At Claridge's Hotel, in London, on the night of January 9th, Mr. George Westinghouse entertained at dinner a large company of British railway managers, financiers and scientists. Two speeches were made of unique interest. One of these was by Lord Kelvin, the other by the host of the occasion. Although no electrochemical subjects were touched upon, these speeches will certainly be of particular interest to our readers, as they are characteristic of the speakers and as the subject of specific American methods in engineering discussed by Mr. Westinghouse should be of general interest.

Lord Kelvin said:

"At this dinner of friends I would like to express a common sentiment which all must feel, our appreciation of the qualities of our charming and beloved host, Mr. Westinghouse. I am sure that Mr. Westinghouse's coming to England reminds us all of the advantages that England has derived from his genius and perseverance and grand skill in bringing out for the public good so many of the results of science and inventiveness. There are many railway men present at this table and many passengers by railways, which means that every inhabitant of our country is represented here. When people belonging to these two classes—the railway men and the traveling public of Great Britain—are gathered together, as now, we can scarcely see Mr. Westinghouse without feeling how much we owe to him for the Westinghouse brake.

"But Mr. Westinghouse has not stopped with his brake. He has gone on, and on and on in America, flashing over again on this side of the Atlantic and bringing his energies here. The present development of the electric industry in the United Kingdom owes its growth largely to him.

"'Largely' is a small word to express how much we owe to him. I do not wish to enter into any comparisons of superlatives, but I do not think any man in the world of engineering could be named to whom more is due than to Mr. Westinghouse for his work in electric engineering.

"Other things besides mechanical engineering and electrical engineering we owe to Mr. Westinghouse. We owe to him the bringing to England, and causing to be appreciated in England, American methods—American methods in a certain way which I may refer to without invidious comparison. American methods of industry and resolution and determination, which are also English methods, because they have been inherited from England. Here it comes back to us with compound interest in the shape of Mr. Westinghouse, and I am sure that we all feel that we are largely indebted to him for what he has done for us, what he is doing for us and, in advance, for what he is planning to do for us in the future.

"We appreciate all this, and we appreciate him as a kind friend, a genial host and entertainer. I ask you to join me in drinking the health of Mr. George Westinghouse."

The toast having been honored with enthusiasm, Mr. Westinghouse rose to respond. He said:

"I wish to thank our distinguished scientific friend, Lord Kelvin, for the complimentary language he has used about me. And I would like to say to all you railway men here present that my life has been very much associated with your calling. I invented the brake of which Lord Kelvin has spoken when I was scarcely twenty-one years old, and thus became acquainted with railway men when the railway industry was rather a poor one compared with what it is to-day. Since then I have closely followed railway operations, becoming acquainted with almost everything that is being done in them; and it is particularly my friendship with railway men which has prompted me to go forward in my work with an interest and keenness that probably would not have resulted from ordinary commercial motives.

"Lord Kelvin has been good enough to refer to my coming to this country. I came here thirty years ago, and for ten years or so I was here about half the time. At that time it was very difficult to get any new thing done in England. I often wanted to sit down and cry, because I could not get anyone to believe in anything. I wanted in those early days to try an iron brake shoe, because, on account of rapid wear, we couldn't keep the wooden one adjusted. I had to beg and beg to be permitted to put a set of metal brake shoes on one tender on the Caledonian Railway. Finally I succeeded. You all know that nowadays all the railway shoes or blocks are made of cast iron or other metal, and are used upon all the wheels of the train.

"Lord Kelvin has alluded to 'American methods.' May I say that one of your English difficulties is inherited I think in an old-world, highly-developed country. After a man (or a nation) has worked prosperously for a long time, he opposes improvement or suggestion, thinking: 'What I have is good enough. I won't try a new thing.' In America, however, the necessities have produced different results. Lord Kelvin speaks of England having sent many men to America. It has also sent to us many ideas. If you take up the American patent records and follow the cases in litigation especially, you will find that among the references cited many are of English origin, some of them containing ideas so complete that wonder is that the inventions disclosed were not established fully and completely in your own land. These records seem to show that Americans and Englishmen have invented the same thing many times.

"In America, however, we have always been short-handed with regard to labor. We have been obliged to find methods whereby one man may accomplish the work of two or three men as compared with your practice here. We have had the best men from Europe—Englishmen, Germans, French, everybody, skilled men, highly-trained men, as well as laboring men. We have combined their experience with our own, coupled it with our necessities, and have thus accomplished results unattainable in a country like this, where you have more labor than you can well keep employed.

"As an illustration of what has been accomplished by the use of electricity in a great industry, I may cite the Homestead Mills of the Carengie Co. Mr. Schwab, whose name is well known to you, is a genius in his way, particularly in the management of men; he is a master in organizing and directing men. Mr. Carnegie believed in him, and if Mr. Schwab made a suggestion in regard to the use of new appliances, even if it involved the tearing down of an old mill and putting up a new one, the new one was ordered. What Mr. Schwab thought should be done was done. As a result of such progressiveness we may see the splendid mills at Homestead, where they pro-

duce, with about 4,000 men, three times as much steel as the Krupp works produce with 15,000 men. The results are simply wonderful. You can start there to-day, in a building containing steel-melting furnaces, and you will there see three men mounted on a car with the charging apparatus, which is moved and operated by electricity. With a few movements of this ingenious contrivance three men charge 20 furnaces, which, prior to the use of electricity, would have required the labor of over 200 men.

"You may go into the yard of the Homestead Mills, where they pile the metal in stock. This yard is covered by a system of overhead cranes, and the result is that not only here, but in the mill and in every other place, you may see great weights lifted and many undertakings going on without a single man exerting himself a bit working not half as hard as I am working now.

"I took some English friends to Homestead. Mr. Schwab, after guiding us through several departments, said: 'I will now show you where we turn out 750 tons of plate girders per day.' The mill was in the shape of an L. We went into the short end of the L, where the furnaces were fed by natural gas, of course, requiring no stokers. The end at which we entered had a rather low roof, and there was in a sight a contrivance like a battering ram in front of the furnaces. Two workmen were sitting down eating their dinners near by; no one else was present. I thought: 'Mr. Schwab has made a mistake; he has asked us to see a mill that is not in operation.' But we went through the mill, which was about 200 feet long. Suddenly we heard a rattle, and then saw a truck approaching loaded with a big ingot. No one touched the truck or the ingot. The load came to a platform; the crane overhead dropped a pair of tongs and quickly put the ingot on the roller table, and as it moved along to the great rolls it was automatically kept in place. The adjusting screws of the rolls were turned by little electric motors, and not a man in that house did a bit of work. It was just as easy as what you are doing now—looking on. We went back to the furnaces. There was a fifteen-year-old boy seated in a little place called the 'pulpit.' He was able, merely by the movement of levers, to open at will any of the furnace doors and move the car along. And we saw this car come in front of a furnace and the charging machine approach and take out of the open furnace a hot ingot, which was dropped on the car and moved off to its work. There was this boy doing absolutely no hard work, and his mill was turning out 750 tons of steel plate each day. My English friends said: 'England has no chance in competition with such methods.'

"Now, all this sort of thing came about in America because of our necessities. We hadn't men enough to do our work. There was a premium in favor of those who could invent machines to work, and thus supply the deficiency.

"At the Carnegie Mills we went to see three blast furnaces. They were making 1,800 tons of pig iron in twenty-four hours. We saw only two or three men on a truck, which was moved automatically. These men were letting the ore run from shoots and mixing it in the required quantity; and when they had filled a truck it was carried up and its contents dumped into a furnace, whence it returned for another load. They were running the metal into an immense receptacle, into which the metal from all three furnaces was mixed. From this place the metal was taken as required, put into a special tank, mounted on a car and taken to Homestead, two or three miles away, to be poured into the furnaces. One heating only was required.

"I refer to all this simply to illustrate the immense advantages we have had in America, and the kind of experience I have been able to bring to this country, and to which Lord Kelvin so generously alluded, and which I hope will be not only useful and profitable, but will establish for the company I represent a name and a position which you will all regard as most satisfactory.

"I want to thank you very sincerely for the kind expressions with which you have greeted me, and especially for your acceptance of my invitation to inspect this evening a couple of inventions, one of which, the Hewitt mercury vapor lamp, is a complete and accomplished thing. The rays of this light are not very pleasant as yet, but the light is likely, however, to be of great value. The other invention, the Hewitt static converter, is quite new, and its object is to convert alternating currents into direct current at so low a cost in comparison with the sums which have heretofore been expended for equivalent results that it is likely, when fully perfected, to cause an immense stimulus in regard to the use of electricity in all parts of England, and particularly in the agricultural parts of the country for farm work and for moving all kinds of vehicles.

"I have taken advantage of these inventions to invite you to see them as my guests, and I thank you for having honored me with your presence to-night."

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*I. Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

By CARL HERING.

## INDUSTRIAL ELECTROCHEMISTRY.

*Nickel Industry.*—What seems to be a good statistical review of this industry in Canada is given in the January 9th number of London *Engineering*. The Canadian and Orford Copper Companies, which have been consolidated with the International Nickel Co., are still the most important producing concerns in the Dominion. The principal works of the Canadian Co. are at Copper Cliff, which covers 10,000 acres of the best mineral land in Ontario, and last year a feature of the company's business was the opening of an immense deposit of nickelliferous pyrrhotite and copper pyrites at the Creighton Mine. Operations were commenced in July, 1900, and now the surface plant is producing from 500 to 600 tons of ore daily for shipment to the roasting yards at Copper Cliff. There have recently been completed extensive smelting works, three-quarters of a mile southwest of Copper Cliff, and these have been utilized for the re-treating of low-grade mattes produced at the Copper Cliff smelters, with the result that their metal contents have been raised from 30 to about 70 per cent. This result is effected by crushing, grinding, calcining and re-smelting the mattes, thus getting rid of a great deal of the rock matter, iron and sulphur and producing an article much nearer the point of refinement and separation of the metals. For the final separation of the copper and nickel, this material is sent to New Jersey. The process includes a series of smeltings with various alkalies, followed by an electrolytic treatment for the purpose of producing pure nickel. One of the companies outside of the combination is the Mond Nickel Co., whose mines at Victoria have been very considerably developed during the past year, the Bessemer process having been put down for turning out the matte. The product is a high-grade article, carrying about 80 per cent. metallic contents in equal proportions of nickel and copper, the iron in the one being at the same time entirely eliminated. This matte is brought to England, where it is refined at the Swansen works by Mond's own process. During the past ten years 1,306,722 tons of nickel,

copper and copper ore, producing 26,606 tons of metallic nickel and 28,070 tons of metallic copper, have been produced in Ontario, the value of the nickel being over $20,000,000 and the value of the copper nearly $6,250,000. The rate of development has been very much greater during the last five years than in the first half of the decade. The most striking development has been in the production of high-grade matte, which in 1897 only amounted to 328 tons, whereas last year it was 15,540 tons.

*Electrometallurgy.*—In the continuation of his series on electrometallurgical problems in the Lond. *Elec. Rev.*, January 9th, Beadle discusses the manufacture of aluminium, magnesium and sodium.

*Separation of Metals from their Ores.* It has been the cause of some surprise that so little attention seems to have been given to the possible application of electrostatic forces to the separation of metals, such as gold, which often exists in very fine particles. The explanation is probably that the forces are too small. It appears, however, that Negreano has had some success in this direction, as he describes such a method in *Comptes Rendus*, December 15th, an abstract of which is in the Lond. *Electrician*. His method is based on the following experiment: A disk is cut out from the center of a metallic plate, and the plate and disk are connected with the two poles of a Wimshurst machine. If now a powdered mixture of sulphur and red lead is blown upon the metallic surface through a wooden sieve, the sulphur will be deposited upon the disk and the minium upon the other plate, or *vice versa*. This is due to the frictional electrification of the two powders in passing through the wooden sieve. He then mixed pulverized silica rock with malachite, iron oxide and copper oxide, and found that the metallic particles could be separated from the silica in the same way. In the case of a quartz rock containing limonite, the separation was easily brought about; also in separating pyrites from a matrix of lignite. The author proposes to employ this method for the separation of gold from gold dust.

*Electrolytic Rectifier.*—In the storage of electrical energy, mechanical methods fail and electrochemical methods must be resorted to in the storage battery. It seems that, similarly, though to a less degree, electrochemical methods may succeed in partly replacing mechanical methods in the rectification of alternating currents and in making cheap condensers. While it does not seem likely at present that the electrolytic rectifier will supersede the present converter or the motor generator, yet there is quite a field of its own, especially for converting small quantities, when moving machinery would be objectionable or expensive. Much has been written about the aluminium rectifier, and it seems that the original experimenters have abandoned it. It is therefore of interest to see that it is now being put on the market in France as a commercial apparatus in a new form, devised by Nodon. The London *Electrician*, January 23d, gives an illustrated description, from which the following is taken: Fig. 1 shows the construction of the electrolytic "valve," as it is called by the inventor.

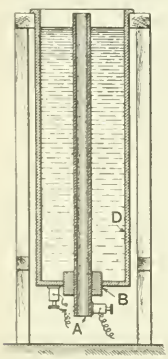


FIG. 1.—RECTIFIER.

It is extremely simple in design, and consists merely of a hollow cylinder A of a zinc and aluminium alloy immersed in a solution of ammonium phosphate. A containing vessel D of iron forms the other electrode, from which the cylinder A is insulated by the rubber plug B. On starting the valve, it merely acts as a liquid resistance, and does not choke back one-half of each alternation. This, however, only lasts for a very brief time, and after a few minutes a film commences to form on the surface of the aluminium electrode. It is this film which permits current to pass in one direction only. In order to utilize both half waves of the alternating current, the Graetz arrangement is used, as shown in Fig. 2. When used in connection with polyphase systems, the apparatus becomes rather more complicated, and it is necessary to use a number of cells equal to twice the number of wires used in distribution. For instance, six would be required for a three-wire, three-phase system. Each cell may be used for rectifying a current having from 50 to 140 volts, but when the voltage exceeds the latter figure two or more cells must be connected in series, allowing 140 volts as a maximum for each cell. Regulation in connection with these valves, having a capacity of more than 4 kilowatts, may be effected either by a choking coil on the alternating current side of the apapratus or by the adjustment of insulating sleeves, which may be made to cover or expose more or less of the aluminium-zinc cylinders. The efficiency is claimed to remain practically constant for all loads, and to seldom fall below 75 per cent. The loss consists in a reduction of 10 to 12 per cent. of the e. m. f., and of a leakage of alternating current within the rectifier corresponding to from 10 to 12 per cent. of the energy utilized. This energy is dissipated in heat which is liberated within the cell, and causes the temperature of the latter to rise to almost 50° C., after which radiation from the metallic casing prevents a further excessive rise. The frequency, within ordinary limits, appears to have no effect on the efficiency of the apparatus. The apparatus is put on the market in groups of four cells, connected as in Fig. 2. These four cells are put together in a frame, and below them a fan is provided; the aluminium cylinders being made hollow, a strong cooling draught passing through them. The current density is made at about 5 ampères per square decimeter of active surface of aluminium. Nodon has also designed an electrolytic condenser on the same principle as his rectifier, which possesses a considerable capacity for its size, for use in starting alternating-current motors and for similar purposes. The rectifier is now being put on the market in sets of cells large enough to deal with 10 kilowatts at the maximum voltage of 140. The price of a complete set of four cells, having a capacity of 5 kilowatts for a single-phase circuit, is $150. The writer of that article remarks that "this price would appear to be almost prohibitive in the case of motors connected to single-phase circuits, but, as the construction of the valve is simple, it may safely be inferred that the selling price would be considerably reduced if there should be a real demand for this apparatus."

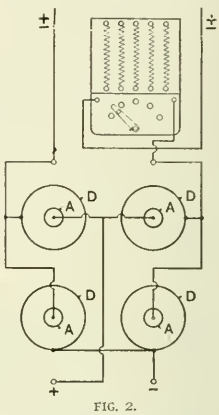


FIG. 2.
ARRANGEMENT OF FOUR CELLS.

An account of some tests made with this apparatus is given by Hospitalier in *L'Ind. Elec.*, December 10th. The tests were made at the School of Industrial Physics and Chemistry of the City of Paris. Four cells were used, and were arranged like a Wheatston bridge, as first used by Graetz for this purpose. One of the diagonal circuits is supplied with the alternating current to be rectified, while the other contains the apparatus in which the rectified current is to be used. As is well known, the former arms each contain one of the "valves." This arrangement enables one to utilize both half curves of the alternating current in the same circuit. The frequency of the alternating current in the experiments was 42, and an electrolytic valve of the 5-ampère type was used. The rectified cur-

rent was used to charge a storage battery of 42 cells in series. The wave forms of the currents and e. m. f.'s were determined by means of the ondograph, and are reproduced in diagram. The efficiency of the rectifier was found to be about 70 per cent., and the wasted energy appears in the form of heat, so that the temperature of the electrolyte increases. This is said to cause no other inconvenience than the evaporation of the liquid, requiring that water must be filled in at intervals. The electrolytic rectifier behaves like a condenser, the current being about one-quarter period in advance of the e. m. f. The deformations of the current wave are the same as are obtained with a condenser, and are due to the presence of higher harmonics.

## THEORETICAL AND EXPERIMENTAL.

*Dissociation of Electrolytes.* The *Zeit f. Elektrochemie*, December 25th, contains a theoretical article by LIEBENOW, in which he discusses the reasons for the discrepancies in Ostwald's well-known formula for the dependency of the electrolytic conductivity of a solution upon its concentration, which formula does not always accord with the facts. As is well known, this formula is in very good agreement with the results obtained for a very large number of organic acids which are relatively only slightly dissociated. For the ordinary inorganic acids and salts which are strongly dissociated, the formula does not agree at all with the facts. Ostwald deduced his formula directly as a consequence of the law of chemical mass action. He considers that state of a solution in which $y$ gram molecules of a salt, say potassium chloride, are dissolved in one liter of water, and in which $x$ of these $y$ gram molecules are dissociated into $x$ positive potassium ions and $x$ negative chlorine ions. There is a constant tendency of the dissociated ions to combine again and to form neutral molecules, and at the same time there exists also constantly the opposite tendency of the neutral salt molecules to dissociate into ions. There is equilibrium if both tendencies balance, *i. e.*, if the number of neutral salt molecules dissociated in a certain time into ions is equal to the number of new salt molecules formed from ions. According to the law of chemical mass action, the first number is $b(y - x)$, in which $b$ is a constant and the second is $ax^2$, in which $a$ is also a constant, hence there is equilibrium if $ax^2 = b(y - x)$. This is the basis of Ostwald's formula. The present author discusses this equation from the point of view of the theory that heat is due to irregular oscillations and movements of atoms. The left-hand part of the above equation then becomes clear. A large number of electrically-charged ions are in rapid movement in the electrolyte. If by chance a positive ion comes into a favorable position with respect to a negative one, they will unite to form a neutral molecule. It is clear that the number of such favorable positions must be proportional to the product of the concentrations of both ions, hence the term $ax^2$ in the above equation. The right-hand part of the equation is not as self-evident; $y - x$ is the number of neutral molecules, and if the number of such molecules which are dissociated into ions in a certain time is to be directly proportional to the number of existing molecules, it would be necessary to assume that such a dissociation is not due to a collision of a salt molecule with an ion, nor of a salt molecule with a salt molecule, but of a salt molecule with molecules of water. In order to explain this, he refers to the Nernst-Thompson rule, stating that there is in general a parallelism between the degree of dissociation and the dielectric constant of the solvent. This rule is easily explained if one assumes that the neutral salt molecules are not really electrically neutral, but that in a KCl molecule, for instance, the K atom has its positive charge and the Cl its negative charge. But the two charged atoms cling together and are not separate ions, but form a molecule which is electrically polarized. According to the ordinary laws of electrostatics, the greater the dielectric constant of the solvent the smaller is the force of attraction between both atoms, *i. e.*, the more is such a polarized salt molecule liable to be ionized if a force to that effect is acting from the outside. Now, such a force would exist if a charged ion comes into the proximity of a polarized salt molecule. The first action of the ion upon the molecule will be to exert a torsion of the molecule so that the ion comes to lie in the continuation of the axis of the polarized molecule. The attracting force of the ion upon the oppositely charged atom of the polarized molecule is then a maximum, and a disruption of the molecule is liable to take place. This is the fundamental conception upon which the author bases his calculations. His final result is $\frac{m^2}{(1-m)v} = A - B\left(\frac{m}{v}\right)$, where A and B are constants, $v$ is the quantity of water in which one gram molecule of salt is dissolved and $m$ is the ratio of the molecular electrolytic conductivity to that for infinite dilution. Ostwald's final equation is a special case of the above, namely, if $B = 0$. As Ostwald's final formula contains only one empirical constant and the above two, it is to be expected that the latter can be made to agree better with the facts than the former. Indeed, the author shows that for potassium chloride the difference between the calculated and the measured values is always less than 1 per cent for a range of concentrations between 0.0001 and 3.

*Phase Rule.*—A long abstract is published in the *Zeit. f. Elektrochemie*, December 25th, illustrated by diagrams, of a lecture by VAN'T HOFF on Gibbs' phase rule, its application to different cases and on graphical methods for representing such chemical problems. He thinks that the very great, but mainly formal, value of the phase rule will never make it superfluous to treat problems of chemical equilibrium in accordance with molecular theories.

*Action of Halogens on Alkalies.*—A contribution to the theory of the action of halogens upon alkalies is given by FOERSTER and MUELLER in the *Zeit. f. Elektrochemie*, December 18th. If a zinc rod is placed in a copper sulphate solution, the reaction is $Zn + CuSO_4 = ZnSO_4 + Cu$. From the point of view of the electrolytic dissociation theory, this equation can be written $Zn + Cu^{\cdot\cdot} = Zn^{\cdot\cdot} + Cu$, where each dot represents a positive electric charge; so that the process may be expressed by stating that the zinc atoms take positive charges from the copper ions, so that the zinc atoms become ions and the copper ions become atoms (exactly the process in the Daniell cell). An analogous consideration may be applied to the action of halogens upon alkali. If this action would be exactly analogous to the above, the equation becomes $X_2 + 2KOH = 2KX + H_2O + O$, where X is a halogen. Or if we write the equations of the ions, it becomes $X_2 + 2OH' = 2X' + H_2O + O$, where the sign ' represents a negative electric charge. It is known, however, that only fluorine behaves in this way, while for the other halogens the process is more complicated. The authors show that the process of the action of any quantity of a halogen upon any quantity of an alkali consists in the formation of two conditions of equilibrium, which are represented by the following equations:

$$X_2 + OH' = X' + XOH$$
$$XOH + OH' = XO' + H_2O.$$

The authors calculate the numerical constants which determine these equilibria and apply their theory especially to the case of the action of chlorine upon an alkali.

*Spontaneous Deozonization.*—If partly ozonized oxygen is left to itself, the proportion of ozone decreases with the time. This phenomenon is known under the name of spontaneous deozonization, and may be due to a variety of causes. WARBURG points out in the *Ann d Phys*, November 12th, that since the amount of ozone at 200 degrees is a state of equilibrium is inappreciable such equilibrium can be attained at ordinary temperatures only by complete dissociation of the ozone. The factors bringing about this dissociation may be external, as for instance, a contact with foreign bodies or with the walls of the vessel; or they may be internal and due to the collision of two molecules of ozone or of a molecule of ozone with a molecule of oxygen. He formulates a mathematical

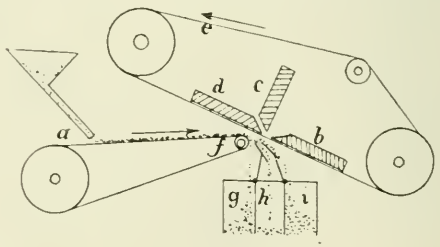
theory of the process, and finds by suitable experiments that the internal effects are almost entirely due to collisions between the gas molecules themselves. Heat increases this internal disintegration much more rapidly than it does the external process, and it becomes the chief agent at high temperatures. He finds that moisture makes no difference to the stability of ozone at 100 degrees. An abstract may be found in the Lond. Elec., January 9th.

## PRIMARY AND SECONDARY BATTERIES.

*Plates Made of Slabs of Active Material.*—The literature on storage batteries during the past month has been scant. About the only matter of interest is an article by Leimer, who seems to have given very much attention to the manufacture of accumulator plates made of a solid slab of material. Such plates are not new, as they were made and tested by the present writer nearly twenty years ago. The difficulty did not seem to lie so much in the making of such slabs, as there are various processes by which this can be successfully done; but it seems to lie more in making and maintaining a good contact between the slabs and the conductors or frame; also in the fragility of the slabs, as those of peroxide are very brittle and become soft in time, while those of spongy lead have at all times very little strength. This direction of development of storage-battery plates has always been a tempting one, although it does not seem to the writer to be a very promising one. However, Leimer's experiences may be of interest and use. The beginning of his description is given in the *Centralbl. f. Accum.*, January 1st. He claims that such plates have the advantage over those of the Planté and the Faure type, in that they have a very high capacity in a small volume and a relatively low weight, and that they are strong and light enough to be used for traction purposes; but they require very careful treatment during manufacture. Although the correct choice and use of the pasting material is of importance, yet the main point is the careful treatment of the plates themselves in all the phases of their manufacture. He has found phenole in aqueous solution to be suitable for a binding material; it forms a basic phenylate with lead oxides, while in alcoholic solutions it does not. For preparing the "solution," he mixed, in his first experiments, 1 part of the purest crystallized carbolic acid (98.8 per cent.) with 15 parts of distilled water. With this solution the minium and litharge are moistened so that they can be shaped by hand without giving off free liquid. For the positive plates, pure minium was used, but not every kind of minium is suitable. He cites a case where, out of ten different kinds, only one would answer. Sometimes a kind of minium is unsuitable, although the percentage of oxygen is high and there are no impurities. The pasting of this material into the frames must be done with great care; all places like corners must be well filled out. When the surface has been made smooth, but still has some holes or depressions, it will not do to fill them up with the mass, as it will always be found to scale off during the formation. In no case should more minium be moistened with the solution than can be used on the same day. The pasted plates should be perforated at once, and should be treated with great care before they are placed into the acid bath. To prevent the mass from sticking on the glass plates before the pasting, the frames are separated from the glass plate by a piece of wood paper. The pasted plates, after having been perforated, are placed with their surface upon a fresh piece of paper, and, with this upon a glass plate, the plates are thus placed above each other, the upper plate being also covered with paper and glass plate. In this condition the plates are left for at least twelve hours, after which they are brought into the drying oven, which is so designed that it is air-tight. During this period a pure, dry, hot stream of air passes through it, the temperature being adjustable. In the stove the plates are placed one above the other in two series, so that each plate touches the next one with the long side. The plates must be exactly perpendicular, and at a distance of at least 1 centimeter to accomplish a uniform drying process on both sides. They should stand, and not lie horizontally, while being dried. At the beginning of the drying, the temperature should not be more than 40 or 50 degrees; after twelve hours it is raised to about 120 or 150 degrees, and this temperature is kept constant for about thirty-six hours. The temperature is then decreased, and the oven is left to itself to cool. After twelve hours the plates, which then have about the temperature of the hand, are placed at once into the acid bath, which should have the same temperature. It is important that the plates should not be left in the ordinary atmospheric air, as he found that this had a bad effect upon them. When prepared by the process just described, they could not well be formed. It was found that the solution of carbolic acid, mentioned above, was too strong; therefore solutions more dilute than 1 ÷ 15 were tried, and finally he found that solutions of 2 to 3 per cent. were the best. Moreover, he found that the plates must remain in the acid bath only for a certain time, and that it is important to keep this at a definite density and temperature. The exact time during which the plates must be left in the acid bath depends upon the porosity and the thickness of the mass. He obtained the best results with thirty-six hours for each 2 millimeter thickness of mass; plates of 140 x 100 x 6 millimeters were therefore left in the acid bath for about one hundred hours. Care must be taken that the acid strength never decreases below 10 degrees Baumé, and when freshly prepared it should not be more than 12 degrees Baumé. If a basin of too small a volume is used, the acid strength decreases very rapidly to zero Baumé. Plates which were left even only a short time in too weak an acid did not stand the formation. In this part of his article he says nothing about the making or maintaining of the contacts.

## MISCELLANEOUS.

*Magnetic Separators.*—In the continuation of his long illustrated serial on the Dusseldorf Exhibition, in the *Zeit. f. Elektrochemie*, January 8th, Danneel discusses a number of metallurgical apparatus which were exhibited. Most of them are purely mechanical, but among them are some magnetic separators. The adjoining diagram shows the Wetherill separator. The finely-crushed ore falls upon a belt *f*, which is moving in the direction of the arrow around two rollers; *d, c, b* are three electromagnets, which form a strong magnetic field. Under the action of the magnetic field, the ore is separated into three parts; the strongly magnetic part drops into the box *i*, the non-magnetic part into the box *g* and that of medium



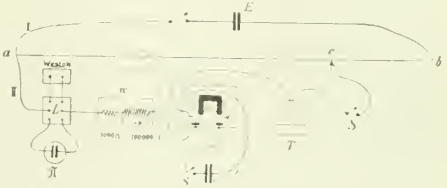

MAGNETIC SEPARATOR.

magnetism into the box *h*. The three boxes are separated from each other by two walls, which are so arranged that when the electromagnets are not excited all the ore drops into the box *g*. A ribbon *e* is provided, moving in the direction of the arrow, in order to prevent magnetic particles from sticking to the magnets. Another magnetic separator which is exhibited is designed by Heberle for a wet process. The particles of ore fall down through a rising stream of water, and are exposed at the same time to the action of a magnetic field. The chief advantage of this construction is said to be that the adhesion between the single particles of ore is so completely removed that the magnetic particles are absolutely free; that is, they are independent of the non-magnetic particles, and are thus enabled

to follow the magnetic attraction. In this way a satisfactory separation of fine powders becomes possible.

*Portable Capillary Electrometer.*—The capillary electrometer is of special interest to electrochemists, as it is especially adapted, in fact limited, to very low voltages; but it measures these with great precision. It is therefore convenient also for measuring the differences between two voltages, be they large or small, providing only that they are very nearly alike. In a recent (Brit.) Physical Society paper SMITH describes an instrument which is a modification of a form of capillary electrometer, consisting of two wide tubes joined by a cylindrical capillary tube, which may be horizontal or inclined. The apparatus contains mercury and sulphuric acid of about maximum conductivity, suitably distributed in the tubes. A spring key is commonly employed with such an instrument, and keeps the two platinum terminals at the same potential whenever the spring is not depressed; when depressed, the terminals are put in contact with the two points, the potentials of which are to be tested for equality. In the instrument shown by the author, the two wide tubes are sealed at the top to prevent evaporation of the sulphuric acid. The wide tubes are also joined near the top by another tube, which allows free motion of the liquids within the apparatus. With this arrangement, the instrument is made air tight, and can, if desired, be made free of air by exhausting the apparatus before sealing. The distribution of the mercury can be altered most easily by means of a third cross piece, which is provided with a tap. To prevent the platinum wires which form the electrodes from being wetted by the acid, if the apparatus should accidentally or during transit be laid on its side or turned upside down, the lower ends of the tubes may be slightly constricted above the ends of the platinum terminals. If the terminals consist of amalgamated platinum foil, the constriction is unnecessary. If a spring key is made of brass, the contacts frequently become unsatisfactory through surface tarnishing; and if, to avoid this, the bearing surfaces are made of platinum, the key may be subject to thermo-electric effects. Such a key cannot conveniently be fastened on the same stand as the rest of the instrument, for, unless the stand and the support on which it rests are very rigid, the pressure necessary to depress the spring produces sufficient movement of the meniscus during the act of depression to render the detection of minute changes of surface tension impossible. These difficulties are overcome by using a key consisting of a U tube closed at one end, communicating at the other with a pneumatic pressure-ball and containing mercury in the bend. Three platinum wires are fused into the tube, so that by squeezing the ball the same change of contacts is produced as by pressing the lever of an ordinary spring key. This form of key can be extended so that a slight pressure applied to the ball makes it work as an ordinary electrometer key, and greater pressure reverses the contacts between the terminals and the points under investigation. With such an arrangement, the sensitiveness of the instrument is doubled, and, by using a microscope magnifying 50 diameters, a P. D. of 1-10,000 volt can be detected without difficulty. The instrument, used as a surface tension galvanometer, is more convenient than an ordinary galvanometer with a magnetic system, because there is no suspension, no lamp and scale, and practically no leveling. An abstract of his paper is given in the Lond. *Elec.*, December 26th.

*Measuring Voltages with the Telephone.*—The telephone has been used for a long time in Kohlrausch's method of measuring the conductivity of electrolytes, but FISCHER has recently extended its application to measuring an e. m. f. or a potential difference, which then enables him to also measure a current by determining the potential difference at the ends of a known resistance. It is based upon Poggendorf's compensation method, as may be seen from the adjoining diagram, in which *a b* is a measuring wire and *c* is a sliding contact; *L* is a battery or other source of current. Between *a* and *c* there are, on the right, the switch S, then the telephone T, an electromagnetic interrupter, a resistance of two coils of 1,000 ohms and of 100,000 ohms, the latter of which can be short circuited, and a switch L, which enables one to put into circuit either a Weston standard cell or the e. m. f. which is to be measured. His electromagnetic interrupter, in which a vibrating spring is used, gives about 600 interruptions per second. The measurement is made after the circuit *a L b c a* has been closed for fifteen minutes. For instance, the problem may be to measure the e. m. f. of a Clark cell on the basis of the e. m. f. of the Weston cell of 1.0100 volts. By means of the switch L, the Weston cell is inserted into the circuit H, which is still open at S. The 100,000 + 1,000 ohms are inserted, and *c* is placed in the center of *a b*, say, on the division 500 if the whole scale is divided into 1,000 parts. The interrupter is then set into action, and the circuit H is closed at S. The telephone will then make a sound; the sliding contact *c* is then moved, say, to 502.0, where the telephone is silent. It starts again when *c* is on 518, hence the minimum is between 502.0 and 518.0;




MEASURING VOLTAGE WITH THE TELEPHONE.

*c* is then placed on 510, which is the middle point between 502.0 and 518.0, and the resistance of 100,000 ohms is short circuited. If, by chance, 510 is the correct point, the telephone remains silent, otherwise it will sound. By an actual test, it was found to be silent between 513.4 and 513.2. The e. m. f. of the Weston cell is therefore assumed to correspond to 513.3. Now circuit H is opened, the switch L is changed so that the Clark cell is inserted instead of the Weston cell and the whole operation is repeated. The e. m. f. of the Clark cell was thus formed to correspond to 719.3 lines of scale; hence it is $\frac{719.3}{513.3} \times 1.0100 = 1.4280$ volts, the temperature being 19.1° C. The value given by the Reichsanstalt is 1.4278. For another temperature it was found 1.4379, while the Reichsanstalt gave 1.4376. The method is therefore quite exact. The weak point in the method seems to be that it is assumed that the main current in the wire is absolutely constant. This could be avoided by the lower circuit duplicated, so that two observers could measure the two e. m. f.'s simultaneously on the same potentiometer wire. The present description is taken from an article in the *Zeit. f. Elektrochemie* January 1st.

*Measuring High Temperatures.*—FERY recently described a new method for measuring high temperatures, based upon the law of Stephan. According to this law, the heat transferred from a radiant body of the temperature T to another body of the temperature t is $A(T^4 - t^4)$ if both bodies have the emission capacity unity. If $t^4$ is small compared with $T^4$, the heat transferred is $AT^4$. According to Kerchhoff, the above condition of the emission capacity, being unity, if fulfilled for bodies inclosed on all sides. This is the case, for instance, in the electric furnace in which the opening through which the radiation passes is sufficiently small. In the author's apparatus the radiation is concentrated by means of a lense upon a thermo cell and its e. m. f. is measured. A comparison of his apparatus with the pyrometer of Le Chatelier gave differences of less than 1 per cent between 1,000° and 1,500° C., while below 600 degrees the differences were greater, on account of the smallness of the deflections of the instrument. The author determined by this method the temperature of the positive carbon of an electric arc lamp at 3,400 degrees. For very high temperatures, this method appears to be quite suit-

able. A fuller description can be found in the *Comptes Rendus*, v. 134, p. 977, and an abstract in the *Zeit. f. Elektrochemie*, November 20th.

## CURRENT NOTES.

American Electrochemical Society.—At the meeting of the Board of Directors, held at Philadelphia, Pa., on January 8th, the following new members were elected: Theron C. Stearns, Jersey City, N. J.; Abraham Van Winkle, Newark, N. J.; Prof. Chas. F. Chandler, New York; Dr. G. Drobegg, New York; Alfred Stansfield, Montreal, Canada; Dr. Victor Goldschmidt, Heidelberg, Germany; Dr. H. W. Wiley, Washington, D. C.; Samuel B. Devlin, New York; Joseph Wetzler, New York; Walter M. Stein, Prismos, Pa.; Dr. Charles Kellner, Vienna, Austria; Dr. Richard Hammerschmidt, Frankfurt a. M., Germany.

At the meeting of the Board of Directors on February 5th the following new members were elected: L. Seeger, New York; Dr. Rud. de Neufville, Frankfurt a. M., Germany; Dr. Hans Landolt, Turgi, Switzerland; J. M. Morehead, Chicago, Ill.; Wm. Smith Horry, Niagara Falls, N. Y.; C. I. Zimmerman, Madison, Wis.; John W. Schlegel, New York; Craig R. Arnold, Sharon Hill, Pa.; A. J. Rodgers, Milwaukee, Wis.; O. M. Thowless, Newark, N. J.; Godfrey L. Cabot, Boston, Mass.; Joseph B. Hall, Chicago, Ill.; Francis W. Higgins, Niagara Falls, N. Y.; Robert S. Allyn, New York; Ralph McNeill, New York; Takakichi Nakayama, Kochi, Japan.

The annual meeting of the American Institute of Electrical Engineers will be held in June, at Niagara Falls. It was found impracticable to arrange a joint meeting of the American Institute of Electrical Engineers and of the American Electrochemical Society in the autumn at Sault Ste. Marie.

Water-power in Norway.—According to a report from Christiana, the Rjukanfoss, in Telemar, known as the Norwegian Niagara, has been sold to a Swedish industrial trust, which will develop its power.

Stevens Institute of Technology.—Mr. Alexander C. Humphreys was formally inaugurated as president of this institute on February 5th.

St. Louis World's Fair.—It is announced that the grounds and buildings will be dedicated on April 30th by the President of the United States, and an address will be delivered by ex-President Grover Cleveland.

Wellesley College is to have, through the generosity of Mr. John D. Rockefeller, an entirely new and up-to-date power plant. Apparatus will be installed for heating all the buildings on the college grounds, which extend over several acres, and the grounds will be lighted by electricity throughout. Electric motors also will be used for operating elevators and blowers for ventilation purposes. Mr. Rockefeller has recently purchased from the Westinghouse Electric and Mfg. Co. for this plant two alternating-current, engine type, two-phase alternators, separately excited, one of 150 kilowatts and one of 75 kilowatts; also a five-panel switchboard.

## *Book Reviews.*

The Electro-Plating and Electro-Refining of Metals. By Arnold Philip. London: Crosby Lockwood & Son; New York: D. Van Nostrand Co. 680 pages. Price, $4.50.

This volume is a new edition of a well-known work, being in the main a reproduction of the last edition of Watt's "Electrodeposition." Chapters on electrometallurgical operations, including the electrorefining of copper, gold, silver, lead and nickel, treatment of tin, production of aluminium, and electrogalvanizing have been added with the view of bringing the work to date.

The book has its chief value in its historical treatment of questions relating to the deposition of metals, and covers quite extensively the field of electroplating in referring to the workshop details of various operations connected with the treatment of metal surfaces.

In the preface, the author expresses a hope that his guiding principle of neglecting theory, except in the most superficial and sketchy manner, will be apparent. This hope can undoubtedly be realized, as not only is theory neglected, but even such well-established laws as those of Faraday, the basis of electrochemical calculations, are not even stated or used as guiding principles in the discussing of various processes. The author excuses this neglect by stating that "a technical text-book cannot and should not deal with explanations of underlying theory, but should assume them." Even should those desiring a text-book on this subject agree with the author on this point, an examination of this book may cause some wonder as to what underlying principles warrant certain statements, such as that on page 498, where it is claimed that the construction of dynamo machines used for copper refining "should undoubtedly be based upon the quality of copper which it is intended to refine by their agency. A dynamo which would fulfill all the requirements of electrolysis of one variety of copper would be unsuited for refining metal of higher resistance."

While we cannot overlook the many good features of Watt's book on electroplating it is difficult, in this day of more advanced electrochemical practice, to find justification for perpetuating statements such as the following which appear in the pages of this new edition. On page 487 a statement, that doubt may be cast upon certain laboratory tests, inasmuch as the current for making them was furnished by voltaic batteries, whereas dynamo current is used in practice, and on pages 313 and 334, that a satisfactory plating can be obtained in about one-half the time with dynamo current than it can with battery current, might convey the impression that current derived from a battery differs very materially in its electrolytic effects from that delivered by a dynamo.

While this work gives a large number of recipes for solutions, describes processes and operations used in connection with the treatment of metal surfaces and contains a fund of information useful to the plater, the instruction as far as it relates to electroplating practice, is decidedly of the rule-of-thumb order. There are few progressive platers, in this country at least, who would find in this book a satisfactory guide in their work. The ampèremeter is mentioned and illustrated in the early part of the book, but its use is hardly referred to throughout the part on electroplating. The effect of current density on character of deposit is not treated, nor are data for proper current density for various metals and solutions given. Information relating to current strength is occasionally lightly touched upon by phraseology, such as "a battery power of three or four pairs is required."

The modern plater is rapidly leaving the rule-of-thumb methods which characterized earlier plating work; he is being guided by theory and classified knowledge, and employing instruments which enable him to calculate and regulate his work to a considerable degree of precision. In using this book, which neglects such guiding principles, he may naturally feel that it is out of date, or written for the amateur rather than the practical man, when, as on page 297, he is advised to carry on the "dipping" operation near a fire-place or in the outer yard. He may also recognize a touch of humor on page 295 where, in describing the operation of the hot lye vat used for cleaning, it reads: "It is easy to ascertain if the potash has lost its caustic property by dipping the tip of the finger in the solution and applying it to the tongue." The positiveness of this method of testing is not a sufficient reason for recommending the tongue as a testing agent, especially where potassium cyanide is made free use of, as it is in many plating establishments.

The first two chapters of the book are new, replacing chapters I, II, III and V of the old book. They deal with the various sources and generators of electrical energy. It may

strike the reader as peculiar that as much space is given to description of the thermo pile, an apparatus which has never become of much practical importance, as is given to the dynamo. The author says that "there is only one form of dynamo which is of any practical use for the electro-metallurgist, and that is the particular form of machine known as the shunt dynamo." This statement could hardly have been made with a full knowledge of the advantages of compounding and of the compound-wound machines which are being installed in many plating establishments in preference to shunt wound dynamos.

The last 200 pages constitutes new matter added to the former work on electroplating. An admirable feature introduced here and one which is not often found in electrochemical books is the extensive treatment of the problem of copper refining from the financial or commercial standpoint. The author calculates the most economical current density, which is shown to depend upon various factors, such as cost of power, labor and rate of interest. He states that a similar line of reasoning may apply in calculation of processes of refining metals other than copper. While this is perhaps the best treatment of the problem which has been published, it is not entirely satisfactory. The counter-electromotive force of polarization which enters as a component of the electromotive force necessary for each tank is not mentioned, though it may play an important part. An item which enters largely in the cost of electrolytic refining of copper, and to a much greater degree in the case of other metals, is the cost of maintaining the solution in constant working condition, either by purifying or regenerating, or by making up new solution from time to time. This has not been included in the estimate of the cost of copper refining.

The new material added by the author has not the same fault of omitting the important working details such as current density and pressure as has the material taken from Watt's book. In the discussion of various processes, references are made to the leading literature on the subject. The author has been handicapped by limit of space for description of various processes and operations and the descriptions are thus somewhat incomplete and superficial. The last chapter, entitled "Electrogalvanizing," describes at length the Cowper Coles process of electrolytically depositing zinc upon iron, where insoluble electrodes are used. He does not mention, however, the processes used most exclusively in this country, which employ soluble anodes.

MONOGRAPHIEN UEBER ANGEWANDTE ELEKTROCHEMIE. Vol V: Die Herstellung von Metallgegenständen auf elektrolytischem Wege und die Elektrogravüre. By Dr. W. Pfanhauser. Halle: W. Knapp. Illustrated. Price, Marks 7.

The author is a manufacturer of machinery, apparatus and chemicals for electroplaters' use, and has thus been kept in touch with the practical side of the subject. He is also a theoretical man, and has written numerous articles for the European technical press. It is therefore not surprising to find in this book a good welding of the theoretical and practical.

The author first gives a brief review of the history of the various attempts to make metal articles by electrochemical means, and then proceeds with a clear, logical exposition of the chemical and electrochemical characteristics of the copper-plating bath. Numerous experimental facts are given, and the explanation of the formation of poor and irregular deposits is strictly scientific. The same phenomenon which has thrown so much light on the working of the lead accumulator—concentration changes in the electrolyte—plays here an equally important *rôle*. For instance, on page 8 it is stated that after seven hours of electrolysis the copper sulphate at bottom of vat was twice as concentrated as at the top. This fact was recognized some years ago by American electrolytic copper refiners. Improvements in the circulation of the electrolyte of the refinery has allowed them to use an increased current density.

The next chapter, on the physical properties of electro deposited copper, is very good, but this is a matter which has not yet been brought to a satisfactory basis.

The latter part of the book is taken up with the various processes for making metallic powders, foil, wire, pipes, thick sheets, etc.

There has been a vast amount of money spent in attempts to electrodeposit copper wire, because cathode copper has a conductivity some 2 to 4 per cent. higher than the same copper when cast from the "refining furnace." These attempts have met as yet with only failure. The Elmore process, it is true, has been brought to a practical producing stage, but its success has been in making pipes and not in making wire.

Another successful application of the electrodeposition of metals has been the manufacture of parabolic reflectors by Cowper-Coles.

In this country seamless copper floats for water tanks are made and some types of switches are electroplated, of which we find no mention in this book. Electroplating might be properly included, but it may be supposed that this other similar process will be treated in another monograph of the series.

It is quite noticeable that the average inventor has an ingenious disregard for commercial conditions. For instance, on page 74 is noted an invention for the direct production of wire. The imaginary cost sheet of the imaginary plant shows a profit of 28,670 marks, corresponding to a profit of 28 per cent. on the capital. Of this, 28,000 marks is due to gold and silver recovered from the anode slimes. These metals are, of course, paid for by any purchaser of "converter bars," and could be of little source of profit except as competing with the electrolytic refiners. There are on our Atlantic Coast half a dozen electrolytic plants in which copper can be refined from "anode to cathode," at a cost of from $3 to $5 per ton.

The last two chapters of the book treat of electrolytic etching and Rieder's electro-engraving process.

PRACTICAL PLATING AND POLISHING. New York: Zucker, Levett & Loeb Co. 114 pages, illustrated. Price, $0.80.

This small book is intended for the use of the practical electroplater. No attempt is made to give theoretical discussions or explanations, but the book is practical in every detail.

After an explanation of the most fundamental terms of electricity, directions are given for setting up and arranging the various apparatus of a plating plant. Then follow special chapters on nickel plating, copper plating, bronze plating, brass plating, silver plating, gold plating, tin plating and galvanoplating. The rules given are worded in concise and simple language, and technical terms are avoided as much as possible, evidently under the supposition that the average electroplater is neither a chemist nor an electrician.

## ELECTRIC GENERATORS FOR CHEMICAL PLANTS.

The increasing use of the electric current in chemical plants involves the question of proper generation of power. There are many factors deciding the location of an industry of this character, and it is not to be expected that all of them can center themselves about a source of energy such as we have in Niagara Falls. It therefore devolves upon the majority to generate their own power with the best means at hand. The prominent method is the use of a steam engine driving a direct current generator.

The requirements of electrolytic work are a large current at a low voltage. It is possible, however, to so assemble the various tanks or process vats that by placing a number in series we can prevent the use of generators of such an extremely low voltage as is called for in the electrochemical process. There are certain elements in the operation of the tanks or vats, however, which render it inadvisable to place too

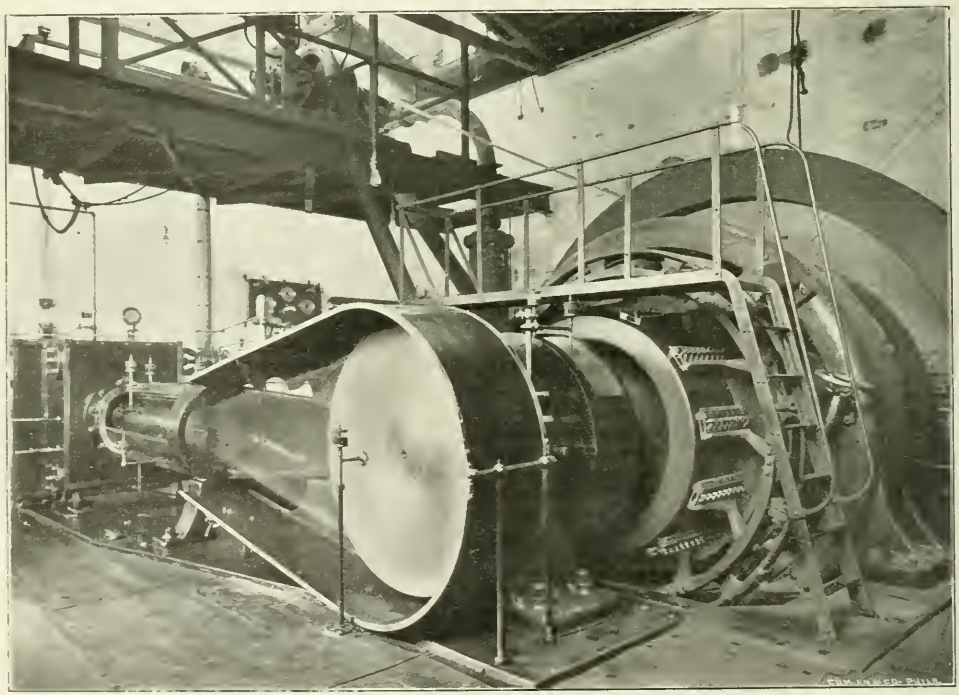
many units in series with the result is the use of generators ranging from about 70 to 125 volts.

It is the heavy current capacity, however, which specializes the generator used for electrochemical purposes, and the services of such a machine calls for the very best in electrical design and construction. The conductors must be amply large to carry the current imposed; the commutator must be of greater size than usual, and all ventilation possible given to the windings and commutator face. The brushes must be of sufficient size and a strong and satisfactory method supplied for transmitting the current from the brushes to the cables at the generator terminals.

The machine will be called upon for practically continuous operation, and abundant opportunity furnished for the observance of its durability and action under the constant full load. It is by the recognition of these facts that a manufacturing firm succeeds in the application of their generators to work of this character. The Crocker-Wheeler Co., Ampere, N. J., have frequently had occasion to apply their standard types of generator to the special work entailed in electrolytic service.

The photograph shown above is a portion of the plant of the Balbach Smelting and Refining Co., Newark, N. J. The cross compound Corliss condensing engines made by the Hewes & Phillips Co. are direct connected to a Crocker-Wheeler generator, furnishing 4,300 ampères at a pressure of 70 volts. The current is used principally in the electric refining of copper, for which this company have been prominently known for years. A smaller portion of the current is used in that part of the plant devoted to the refining of gold, silver and lead. Upon the gallery in the background of the cut is shown a dynamo, belt-driven from the large engine below, and furnishing current at 125 volts for the driving of the power motors and lights used about the works.

The main generating unit is interesting as being typical of this type of machine, with its large commutator face and high current output in proportion to the size of the generator. Other prominent electrolytic plants using Crocker-Wheeler generators are the Buffalo Smelting Works, Buffalo, N. Y.; the Perth Amboy plant of the American Smelting and Refining Co., and the De Lamar Copper Refining Works, Carteret, N. J., representing over 3,000 kilowatts of power.



PLANT OF THE BALBACH SMELTING AND REFINING CO.

## AN ELECTRIC PROCESS FOR PURIFYING WATER.

Electrochemical work, as applied to the purification of water, is the result of adapting well-known laboratory experiments to industrial practice on a large scale. We recently inspected a plant designed for this purpose and exhibited at the office of the American Electric Improvement Co., Philadelphia, Pa. While this is only an exhibit plant, the company state that the process, which is based upon patents of Mr. C. C. Clark, has passed the experimental stage, and that they are now filling orders for industrial plants.

The adjoining illustration, Fig. 1, shows diagrammatically the construction of the apparatus, the whole length of which is 10 feet. While at first sight the diagram may look somewhat complicated, the construction is really very simple, and may be easily understood; 26 is the water inlet and 52 the water outlet. The water, having entered the apparatus through 26, passes into the electric chamber, containing a series of electrodes 29 and 30. There is always a negative electrode following a positive electrode, and, *vice versa*, the positive electrodes being marked 29 and the negative ones 30 in the diagram. Connections of the electrodes with the positive and negative pole of the current supply are made by the wires 32 and 33, which pass through the cover of this box and are connected with the electrodes in the manner shown in the diagram.

The voltage used in the plant visited is 240 direct current. The electrodes are perforated, as shown in Figs. 3 and 4

While the water passes downward through holes 31 decomposition of the foreign substances takes place, and the mixture thus produced of purified water and of the products of the electrochemical decomposition leaves the electric chamber through the hole 42 in the bottom, and then enters the large and long cylinder 7.

While the water inlet 26 has a small diameter, this cylinder has a large diameter, the object being to produce a relatively low speed of flowing through the cylinder with the large diameter, in order to enable those products of decomposition which have a higher density than water to settle down, and those which are lighter, such as the gases developed, to raise upwards to the top of the cylinder.

The principle of the apparatus is therefore to first decompose the impurities in the water in the electric chamber, and, second, to remove afterwards these impurities by purely mechanical means in the large cylinder; 44 are the blow-off pipes for discharging the heavier impurities. In the plant visited a dark brown muddy liquid, nearly solid, was discharged through them. The gases which are developed are left off through 48. The water thus freed from its impurities is led off through the outlet 52.

The inventor states that various materials have been found to be suitable for the electrodes, but that he has obtained his best results with copper and Acheson graphite electrodes. It is claimed that the wear and tear of the electrodes is small.

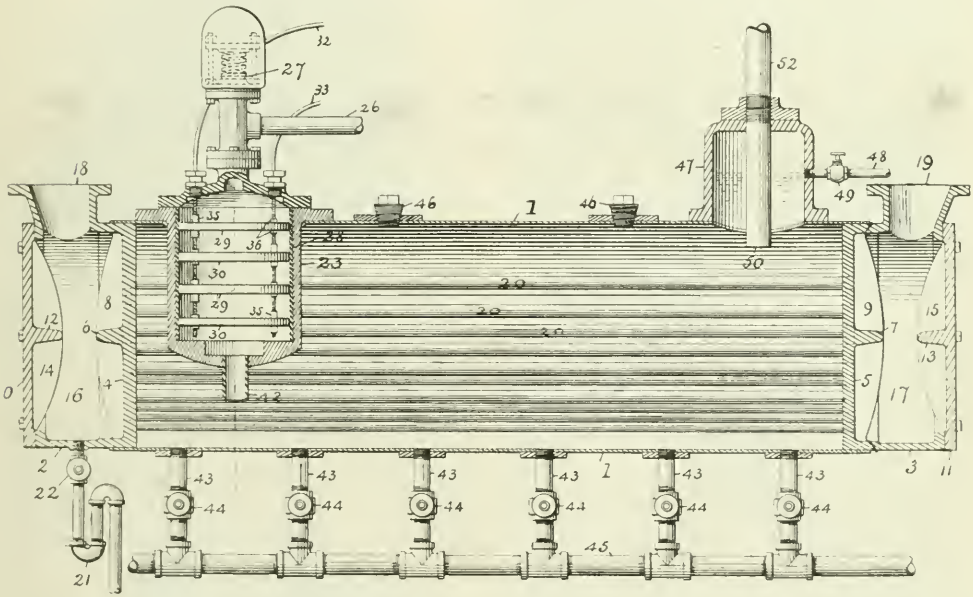
We may now describe the details of the apparatus. Referring to Fig. 1, the cylinder 1 is a close and tight receptacle, into the ends of which are secured circular heads having outer cylindrical rings 2, 3; inner plates 4, 5, which form tube sheets, with stiffening ribs 6, 7, 8, 9, removable covers 10, 11, with ribs 12, 13, 14, 15, so that circulating chambers 16, 17 are formed, having openings 18, 19, to which may be attached the necessary pipes to convey cooling water or steam into or out of chambers 16 and 17.

The tubes 20 extend from tube sheet 4 to tube sheet 5, their ends being secured in expansion stuffing boxes. Cold water is passed through these tubes for artificial cooling when salt water or other liquids of a high conductivity are electrolyzed. When used as a feed-water heater and purifier, steam is passed through the tubes 20, generally exhaust steam. A drain pipe 21 connects to the bottom of chamber 16, and valve 22 opens and closes the pipe, and is only used to take away the water of condensation when the apparatus is using steam.

26 is the inlet pipe for the inflowing liquid to be treated, and above it is located a suitable relief valve 27, having means to relieve any excess of pressure above a fixed limit.

The electric chamber 23 has an insulated lining 28. The method of suspension of the positive and negative electrodes 29 and 30 is best seen in Fig. 3. The current conductors 32 and 33 are are provided with insulation 35 and with conducting nuts 36. At the sides of the cover 24 are insulated stuffing boxes 37, the patented construction of which is best seen in Fig. 5.

The heavy impurities which settle down at the bottom of the cylinder can at any time be drawn off through the pipes 43, controlled by the valves 44 and connected to the discharge pipe 45. When a thorough cleaning is necessary, the wash-




APPARATUS FOR PURIFYING WATER.

out plugs 40, at the top of the cylinder, may be removed, giving access for the introduction of a hose.

In the dome 47 the light, floating impurities are gathered, which may be drawn off by the pipe 48, controlled by valve 49, while the outflow pipe 50, for the purified water, descends below the dome and into the cylinder to the body of pure water.

The action of the apparatus is continuous during the supply of liquid and electric current, and when once set in operation it is automatic, in so far as the electric current (furnished from ordinary constant potential mains, as for lighting, etc.) will vary according to the conductivity of the liquid to be treated, *i. e.*, the less impurities are in the water the greater its resistance and the smaller the current.

Fig. 2 is a cross section of the inlet chamber. Fig. 3 shows plainly the construction of the inlet chamber, and Fig. 4 is a plain view of the electrodes.

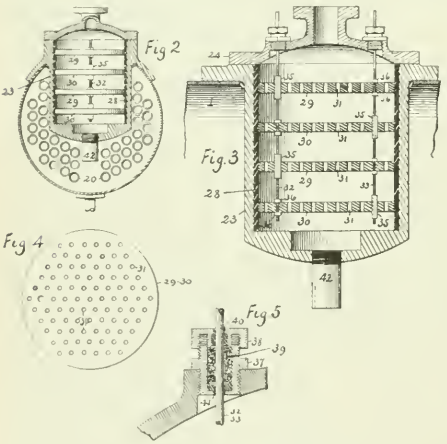
The apparatus is claimed to be suitable for a great many industrial purposes, the most important one being probably for the supply of pure water for boilers. Other applications are said to be the purifying of the water pumped from mines so that it may be used for commercial purposes; the changing of

sea water to fresh water for use on steamers; the purifying of water for manufacturing purposes, ice plants, hotels, office buildings, the purifying of sewage, etc.

The main point is, of course, the question of cost, and the inventor claims that in this respect his process is far superior to all other methods of purifying or distilling water. For an average price of electric energy (based upon the cost of generating electric energy by means of Corliss high-pressure engines, with a price of $2.50 for coal) he states that, according to a calculation made by an electrical expert, 360 gallons of fresh water can be purified at a cost of one cent by his process. This cost can still be considerably diminished if the most improved and most economical methods of power generation are applied, as found in modern power plants.

The cost for attendance is, of course, very small, as all the attendant has to do is to discharge the pipes 44 and 49 at intervals. There is no complicated device on the apparatus which might be liable to be destroyed by the carelessness of the attendant.

Another interesting application to which the apparatus is said to be well adapted is the purification and aging of alcoholic liquids. The liquor, after the treatment, is found to be pure. It is said that by this system whiskey direct from




DETAILS OF APPARATUS FOR PURIFYING WATER.

the distillery can be aged at a cost of 1½ cents per gallon, and that, after having been treated in the apparatus and stored in a charred barrel for thirty days, it is found to be equal to the best whiskey in the market. This method should therefore represent a great saving over present methods in the expenses for storing, interest and insurance. The apparatus used for this purpose contains a filter near the outlet, in order to remove impurities which have the same specific gravity as the liquor, and which therefore do not settle down or raise up in the large cylinder. Otherwise the apparatus is the same as that for purifying water.

## ELECTROPLATING DYNAMOS.

The building of a dynamo for electroplating or any low voltage work involves difficulties not encountered in ordinary machine design. Of course, the two great problems to be met lie in taking care of the heavy current without undue heating, both in the windings and at the commutator, and in the prevention of destructive sparking at the brushes. In other words, commutating the relatively large amount of current. Scientific design will avail nothing in this branch of the work without a generous allowance of iron and copper.

The Holtzer-Cabot Electric Co., Boston, Mass., are manufacturing a line of machines designed especially for work of electrochemical nature. A cut of one of the machines is shown herewith, the machine in question being capable of delivering 700 ampères at 6 volts. It will be noted that the machine is quite compact, this being necessary to ensure short, massive magnetic circuits, giving economy of exciting energy. These machines are made in two, four, six or eight-pole designs, according to the size. The armature is shown in Fig. 2. The coils are arranged cylindrically around the armature, and are made of heavy copper bars, the length being just great enough to enable a loop of the proper span to be formed. An exceedingly important feature in machines of this kind is the armature resistance, which is quite low in these machines, owing to shortness of the circuits. The windings are so

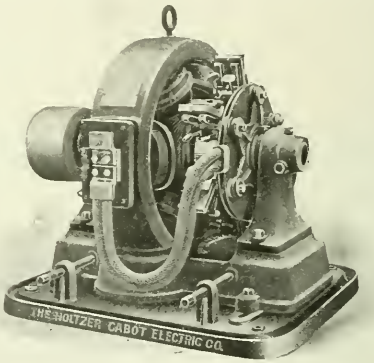



FIG. 1.—ELECTROPLATING DYNAMO.

arranged that the air may circulate freely through the conductors for ventilating purposes, which is also important. The arrangement of the armature conductors is such that, in case of injury, a coil may be replaced by simply lifting a few of the adjacent coils, it being unnecessary to strip the armature, as would be the case in many forms of windings.

The commutator is necessarily of heavy construction, with sufficient copper to make the current density very low, leaving a wide allowance for frictional heat due to the unusual area of brush surface. These segments are of pure copper, rolled to increase their density, thereby giving greater conductivity and lengthening the life of the commutator. The brush holders

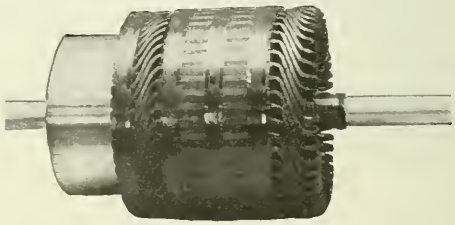


FIG. 2.—ARMATURE.

are of the tangent type, and are made especially for the carrying of heavy current. The spring is flat and loop-shaped, and is long and heavy, allowing extremely delicate adjustment, so that the brushes are held upon the commutator with a firm pressure, but without causing undue frictional heat. Provision is made for carrying the current from the brush itself to the portion of the holder which clamps the stud, so that the spring or sliding contacts are not depended on to carry current. The pedestals are so arranged that upon occasion the armature may be removed without disturbing the connections, it being simply necessary to raise the brushes and slide off the front or rear pedestal, carrying it out of the way in order that the armature may be removed. Compound winding is usually employed.

On larger machines it is often necessary to employ a double

commutator. Fig. 3 shows a machine of this kind, built by the Holtzer Cabot Electric Co., for delivering 4,000 amperes at 6 volts. This machine is intended primarily for the electrolytic reduction of copper ore, but is, of course, suitable for any work requiring a large quantity of current at a low voltage. In this machine the poles are eight in number, and are of wrought iron, cast welded into the ring. The poles are fitted with a special form of shoe, which is of such a shape as to pre-

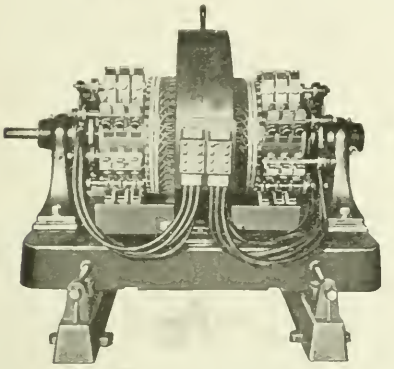


FIG. 3.—4,000-AMPERE DYNAMO.

vent the field flux from being distorted by the back magnetization of the armature. Thus the diameter of commutation remains constant, and it is not necessary to shift the brushes with changes of the load. The armature for this machine is assembled on a spider, provision being made for circulation of the air through the inner parts of the machine and out through the winding. On all these low-voltage dynamos the speed is made purposely quite low to reduce friction as much as possible and secure cool and efficient operation.

## *Personal.*

DR. J. J. THOMSON, of Cambridge University, England, has been appointed head of the department of physics of Columbia University, New York City, to succeed the late Ogden Nicholas Rood. Prof. Thomson was born in 1856, and is best known by his famous researches made in recent years on corpuscles or "masses smaller than atoms."

MR. CRAIG R. ARNOLD, of Philadelphia, is going to the South, and to Mexico, to report on the application of electrolytic gold processes to certain mines.

MR. J. WALTER WELL has resigned the position of Provincial Assayer for Ontario, in order to specialize along certain lines affecting the mining industry in Ontario. Mr. A. G. Burrows has been appointed to succeed him.

MR. ANDREW CARNEGIE has notified the Provost of Greenock, Scotland, that he is prepared to give $50,000 to erect a memorial to James Watt, the inventor, who was born in that city on January 19, 1736, in recognition of his engineering achievements; or he will head a movement in America to raise a large fund which, in conjunction with sums raised in Great Britain, will provide for a more extensive scheme of commemoration.

COUNT CORRADO EMO-CAPODILISTA, of Milan, Italy, was recently in the United States for the purpose of making a study of the electrical and electrochemical industries as developed here.

MR. GEORGE H. GIBSON has resigned his position with the Westinghouse Co's publishing department, Pittsburg, Pa., to accept a position with the B. F. Sturtevant Co., Jamaica Plain Station, Boston, Mass., the well-known manufacturers of blowers, heating, ventilating and forced draft apparatus, electrical machinery and steam engines. Mr. Gibson was formerly a member of the editorial staff of the *Engineering News*, of New York City, and is a graduate of the Engineering School of the University of Michigan.

## OBITUARY.

We regret to report the death of MR. A. T. WEIGHTMAN, who was well known among the electrochemical fraternity of this country as the electrochemist to the Electrical Lead Reduction Co., Niagara Falls, N. Y. Owing to failing health, he recently resigned this position and went to England to recuperate. He died in London, on February 3d. He was a member of the American Electrochemical Society, and at the Niagara Falls meeting he read a paper on the scientific principles of the Salom lead-reduction process.

## INDUSTRIAL NOTES.

THE OHIO BRASS CO. have decided to substitute alternating-current power distribution for the direct-current system at present in use in their shops at Mansfield, Ohio. A recent purchase from the Westinghouse Electric and Mfg. Co. comprises a 180-kilowatt, 7,200 alternation, two phase alternator, a direct-current exciter, switchboard equipment and the following induction motors: two of 40 horse-power, four of 30 horse-power, one of 20 horse-power, one of 15 horse-power and one of 2 horse-power. The alternating-current motors have been chosen on account of their low cost of maintenance and freedom from break-down.

THE SUSQUEHANNA IRON AND STEEL CO., Columbia, Pa., are about to install an electric-power distribution plant in their mills. A recent purchase from the Westinghouse Electric and Mfg. Co. comprises a 400-kilowatt alternating-current generator, one 200 horse-power induction motor and 300 to 400 horse-power in motors, ranging in size from 50 to 20 horse-power.

THE AMERICAN ELECTRIC IMPROVEMENT CO., Philadelphia, Pa., are installing a water-purifying plant for the T. A. Harris Co., Continental Dye Works, Philadelphia, Pa.

THE ANACONDA COPPER MINING CO. are about to put in operation a new 5,000-ton-per-day reduction plant, which will be equipped with electrical apparatus for power distribution. A recent contract with the Westinghouse Electric and Mfg. Co. embraces seven motors, of an aggregate of 185 horse-power, to be added to the present installation of about 30 Westinghouse motors, of an aggregate of over 1,000 horse-power.

THE ST. JOSEPH AND ELKHART POWER CO., Mishawaka, Ind., are installing a large hydraulic plant on the St. Joseph River, near Mishawaka, including power house, dam and hydraulic and electric equipment, for the generation and transmission of electric power to the cities of South Bend, Mishawaka and Elkhart, Ind., and adjacent territory. The energy will be used for general lighting and power purposes. The consulting engineers and general contractors for the complete development are Sanderson & Porter, 31 Nassau street, New York City, who have recently purchased from the Westinghouse Electric and Mfg. Co. four 1,000-kilowatt, 13,200 volt, revolving field alternators and two 125-kilowatt, direct current exciters. The machines are all to be direct coupled to horizontal-shaft water wheels.

TRADE CATALOGUES.—We have received trade catalogues from the following companies: Fort Wayne Electric Works, Bulletins 1,037 and 1,038 (Mast arms). The B. & B. commutator towing device) and flyers 4,040 and 4,041 (Primary fuse boxes. Type a transformer "strikes"). Fred. M. Locke, Victor, N. Y. (Victor insulators). Alphaduct Mfg. Co., New York (Alphaduct flexible conduit). Alberene Stone Co., New York (Alberine stone for use in high potential work). Crouse-Hinds Electric Co., Syracuse, N. Y. (Norbitt porcelain electrical appliances).

THE MATLACK PLATINUM WORKS, Sugartown, Pa., owned by J. Bishop & Co., were recently destroyed by fire, which was started by burglars.

THE MEXICO MINE AND SMELTER SUPPLY CO., Mexico City, Mexico, have recently ordered several centrifugal pumps from the Morris Machine Works, New York, N. Y.

## DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

*Compiled by Barnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.*

*This digest of electrochemical United States patents prior to July, 1902, will be one by classes, setting out for comparison in each class those devices which have the same object, or those methods which seek the same results. In each class the patents will be arranged chronologically. The digest will be complete in the sense of covering every point which is touched upon in the original specification.*

(Continued from page 196.)

518,710. Henry Carmichael, Malden, Mass., April 24, 1894.

Rectangular vessel has sides of glass or slate and trough-shaped bottom of iron, with vertical parallel ribs, serving as cathode. Anode compartment, a rectangular box having a trough-shaped bottom of asbestos, stiffened with hydraulic cement, resting on cathode ribs. Sides of vessel extend up around sides of anode compartment, and serve to collect hydrogen. Some of the cathode ribs extend up into the hydrogen-collecting chambers. Anode, lumps of gas carbon or magnetite, supported on a net of platinum wires carried by platinum pegs, which pass into an insulated frame and conductor of heavy copper wire. Gradually feeds brine into cell through perforated pipes opening upwardly against anode, thus washing it and maintaining a zone of brine between anode and cathode. May suspend basket of salt in anode compartment. Cathode ribs direct caustic to middle of bottom, along which it flows, increasing in concentration, to an outlet at one end. A siphon delivers caustic in drops through a layer of petroleum, preventing short circuit and excluding air. Caustic diffusing through diaphragm conducted back by a horizontal pipe lying on diaphragm, and opening through it into cathode compartment at end remote from outlet. Inflow of brine proportioned to outflow of caustic, and causes downward movement in anode compartment, hindering upward diffusion of caustic. Increases difference of specific gravity of anode and cathode solutions by surrounding anode compartment with lagging to retain heat, while iron base and ribs conduct away heat. Base may also have external corrugations. Delivers a broken stream of brine to the feed pipe by a rotating scoop. Shows a plurality of cells electrically connected in series, with common supply and discharge pipes.

A second form of apparatus employs a circular glass bell and iron base, between which is clamped a conical diaphragm, delivering the hydrogen to a central collecting chamber. Radial cathode ribs on the base form a tortuous passage, delivering caustic to a central outlet. Pipes for supplying brine and delivering chlorine and hydrogen pass through base. Cathode ribs may extend upwardly into hydrogen chamber.

A third form of apparatus for electrolyzing sodium sulphate, similar to second form, but has side outlet for sulphuric acid.

522,615. Isaiah L. Roberts, Brooklyn, N. Y., July 10, 1894.

Vessel, a U-shaped glass tube, with central supply pipe. Salt fills pipe and bend of tube, serving as diaphragm. Anode, limb of U tube filled with broken coke or charcoal, receiving a carbon rod conductor; iron cathode in other limb. Caustic outlet in bend. Modification, using rectangular vessel, divided transversely by a narrow, perforated box of glass or stone ware, filled with salt. Anode compartment filled with broken carbon.

522,616. Isaiah L. Roberts, Brooklyn, N. Y., July 10, 1894.

Iron vessel, serving as cathode. Diaphragm, a bag of wire netting and cloth or asbestos, within which is a perforated or porous jar of unglazed porcelain, the space between being filled with sand or powdered anthracite. Porous jar filled with salt, into which depends the charcoal anode. Cell closed at top by wood or tile, soaked in paraffine and wax. Glass ring insulates diaphragm from iron vessel. May use tubular charcoal anode, receiving a perforated salt-supply pipe.

522,617. Isaiah L. Roberts, Brooklyn, N. Y., July 10, 1894.

Similar to preceding, but has drain pipe from anode compartment to remove such impurities as sulphuric acid and chlorides or sulphate of aluminium, iron and calcium.

522,618. Isaiah L. Roberts, Brooklyn, N. Y., July 10, 1894.

Same as 522,616.

525,732. September 11, 1894; Emile Andreoli, London, England.

A series of narrow anode and cathode compartments are separated by diaphragms of porcelain, made of powdered pumice and asbestos or infusorial earth. The anodes may be of metal, e. g., iron, peroxidized lead or platinum, or of retort carbon, ground flat on side facing cathode. Anodes have necks passing through holes in a slate cover, a tight joint being made by a cement of ground asbestos, porcelain and litharge, and by a winding of paraffined string. A system of pipes gives a forced circulation through all the compartments of each cell and through several cells in succession.

534,033. February 12, 1895; Thomas Craney, Detroit, Mich.

Evaporates caustic soda solution in cast-iron kettles, and passes an electric current from a carbon anode to each kettle to purify solution. Current converts metallic oxides dissolved from metal of kettles into insoluble higher oxides, which settle out.

541,146. June 18, 1895; Henry Blackman, New York, N. Y.

Returns brine to cell, after saturating and cooling it. Cooling pipes pass through cell. Shows various cells, one containing a series of alternating plate electrodes of platinum and zinc.

549,189. November 5, 1895; Thomas Craney, Bay City, Mich.

Anode compartment, a vessel of perforated metal or wire cloth, serving as cathode, lined with asbestos. Sides have an insulating lining. A body of broken carbon rests on the asbestos and serves as anode, contact being made by protected carbon pencils depending into it. Outer vessel of iron, which may also act as cathode. Pipes lead to and from anode and cathode compartments.

552,895. January 14, 1896; Thomas Craney, Bay City, Mich.

System employing a tandem series of the cells shown in patent 520,257. Pipes connect anode and cathode compartments respectively. Anode solution from last cell freed from chlorine and returned. Caustic solution from last cell falls through a carbonating tower, and may be converted into either normal or acid carbonate. If normal carbonate, it dissolves, heat being used if necessary, but is partially precipitated in a cooling tower, the residual solution returning to cathode compartment of first cell. Bicarbonate precipitates partly in carbonating tower and partly in cooling tower. Conveyer removes carbonate to a draining bin.

552,955. January 14, 1896; Thomas Craney, Bay City, Mich.

Solution from last cell descends through a high stand pipe against a rising stream of carbon dioxide. Bicarbonate removed from bottom, partially dried in a centrifugal, fully dried by a mixture of hot air and carbon dioxide, and ground. May wash out any traces of salt by a bicarbonate solution thrown into centrifugal. Residual monocarbonate solution from a stand pipe returned to cathode compartment of first cell.

559,038. March 10, 1896; Michael H. Wilson, Brooklyn, N. Y.

Electric current carried to and from electrolyte by two falling streams of water flowing through or around metallic terminals above cell. Water streams may fall free or descend through vertical, perforated glass tubes, opening through top and bottom of cell. Partition depends from cover of cell, partially dividing salt solution.

560,518. May 19, 1896; Jules Meyrueis, Paris, France.

Diaphragm cells arranged in cascade. Pipes carry electrolyte through successive cathode compartments. Acidifies concentrated brine in anode compartments with hydrochloric acid. Delivers caustic solution to a boiler containing litharge, which dissolves and is re-precipitated as white lead by a stream of carbon dioxide. Residual liquor further carbonated and sodium bicarbonate crystallized out. Solution then returned to cells.

# Electrochemical Industry

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## Electrochemical Industry

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## THE BRUSH STORAGE BATTERY PATENT.

Secondary or storage batteries, consisting of lead and lead peroxide electrodes in sulphuric acid, were the first electric accumulators of any practical value. In 1856 Gaston Planté began his investigations, which extended over a period of several years, on the formation of accumulators of this type. His method of formation was purely electrochemical, starting with metallic lead, in the form of sheets, which he submitted to the action of an electric current in dilute sulphuric acid. His process was tedious and expensive, requiring a great number of reversals with intermissions of repose on short circuit. On account of the enormous expense of converting metallic lead into active material by this original Planté process, the *original* Planté battery cannot be said to have ever had a commercial existence.

On October 20, 1880, Camille A. Faure, a Frenchman, patented in France an improvement on the Planté battery, which consisted in mechanically applying active material to a conducting support, thus producing instantly a plate, the manufacture of which by the original Planté process required months. A corresponding patent was issued to Faure in the United States on January 3, 1882, No. 252,002. On March 2, 1886, United States patent No. 337,209 was issued to Charles F. Brush, Cleveland, Ohio, covering this same invention. After years of litigation and the expenditure of large sums of money, the United States Circuit Court of Appeals handed down a decision on October 4, 1892, in a suit of the Electrical Accumulator Co., owning the Faure patent, against the Brush Electric Co., owning the Brush patents. The court upheld the Brush patent, No. 337,209.

Some portions of this famous decision are of lasting interest, and are worth recording even at this late date:

> (3) The invention described in letters patent No. 257,005, issued January 3, 1882, to C. A. Faure, a citizen of France, for an improvement in secondary batteries, having been conceived by the patentee in France, and being covered by a French patent issued October 20, 1880, he cannot claim the invention in this country prior to the latter date, as against a citizen of the United States who, being an original inventor, subsequently received an American patent.
>
> (5) Brush's patent, No. 337,209, was not anticipated by the patent of April 3, 1866, to George G. Percival, for secondary battery electrodes, consisting of cells filled with coarse conducting powder and divided by a porous partition, or by the patent of April 23, 1867, to George L. Leclanche, for a "polarization apparatus or electric accumulator," consisting of two plates of graphite or unoxidizable metal buried in two flasks of powdered graphite moistened with a liquid which is a good conductor, such as potash water.
>
> (9) The Brush patent, No. 337,209, was not invalidated by patents Nos. 260,653 and 276,155, issued to him prior to 1886 for improvements subsidiary to the main invention, for their subsidiary character appears on the face of such patents, although, owing to delays in the Patent Office, they were issued before the patent for the main invention.
>
> (10) The Brush patents, Nos. 337,209 and 260,099, did not expire with the Italian patent issued to him August 8, 1882, for division D of the Italian patent was designed to cover, not the

[illegible] mechanical operation made in 1882, of plates specially prepared for the purpose of more rapidly forming active material thereon by the Planté method of electrical disintegration.

(III) The Brush patent, No 260,090, must be limited to electrodes on which the active material is made by applying the Plante method of electrical disintegration or other "forming" process to plates which are ribbed, honey-combed, studded or equivalently prepared.

(IV) When an inventor makes a generic invention, and also subordinate specific inventions, and presents the whole series in a set of contemporaneous applications, he cannot be allowed, by subsequent amendments, couched in general terms, to enlarge the boundaries of each invention so as to extend each into the borders of another, and thus obtain a series of overlapping patents.

Patents Nos. 260,653, 260,090 and 276,155, referred to above, were patents issued to Brush for subsidiary improvements prior to the issue of his broad patent, No. 337,299, in 1886. It was held by the defendants that division D of an Italian patent, issued to Brush on August 8, 1882, disclosed the invention claimed in Brush's broad patent of 1886. This claim was overruled, as shown above. Had this defense been successfully maintained, the Brush patents would all have expired in this country August 8, 1887, or about a year after the issue of the principal patent.

Immediately after the issue of the Faure patents, and as a consequence of the notoriety given to the invention by Lord Kelvin's sensational announcement that he could hold in his hand in a small box 1,000,000 foot pounds of stored energy, the field of storage-battery research became the most extensively worked of any subject of electrochemistry. Hundreds of inventors began to work all the probable changes of form in the "grid" or conducting support. An idea of the activity in this field may be obtained by considering that prior to the Faure patent, No. 252,002, there had been issued in the United States in the whole only nine patents on storage batteries. In the first year following the issue of the Faure patent 27 United States patents were granted on this subject; in the second year 43, and in the following years 37, 25, 23, 18, 50, 93, 92, 36, 43, 35, 32, 28, 30, 42, 27, 45, 53, 52, 94. The last figure refers to a little more than a year, as it comprises all patents issued since January, 1902, up to date. It will be seen that there was an immense activity immediately following the Faure patent, and that, while this activity was greatly abated during the period of litigation, there has not been a year in which the number of patents issued was less than twice the total number issued prior to the Faure patent.

The commencement of litigation, involving the mechanical application of active material to a conducting support, caused attention to revert again to the Planté method of formation, it being desired to find some method of avoiding the Faure and Brush claims without the expense and waste of time necessitated by the original Planté method. It was soon found that the corrosion of metallic lead with the formation of active material not mechanically applied could be accomplished in a comparatively short time, and even in a few minutes, by using oxidizing electrolytes instead of sulphuric acid, or in addition to sulphuric acid. It was found also to be practicable to convert the metallic lead by purely chemical means, without an electric current, into active material, which was equally adherent and efficient with the mechanically applied.

These discoveries, it will be seen, practically disarmed the owners of the Brush and Faure patents, hence it does not seem probable that the recent expiration of the Brush patent, No. 337,299, will have any very marked effect upon the commercial aspect of the storage battery. This is particularly shown in the fact that the leading storage-battery company of this country, and the one which has controlled the Brush patent, have for a number of years, to a large extent, abandoned the mechanical application of active material.

It has been found by the company referred to that for most purposes positive plates made by a modified Planté or electrochemical process, and negative plates made by casting a grid around a compound of lead, and subsequently reducing the same, have been more satisfactory than the mechanically applied or "pasted" type. It is worthy of note in this connection, however, that one of the most recent and apparently successful types for the specific purpose of operating automobiles is of the pasted type which has now become public property. There is no telling what effect the expiration of the Brush patent may have on the commercial development of this particular type of batteries for automobile purposes.

## PROGRESS IN ELECTRIC-FURNACE WORK.

It is a curiously persistent and recurrent feature in the development of almost all new arts that after the disclosure of the new field paths are found leading into it from every direction, and the feeling is rather one of wonder that it remained so long undiscovered than of surprise at its discovery. Thus, after the development of the first reproducer of speech, it became apparent that a wide range of devices, from the arc to the electroplating vat, could be so manipulated as to produce the effects. Again, the discovery of new sources of the Becquerel rays and allied emanations have proceeded apace, until it would almost seem that in the end their presence will be detected wherever energy is undergoing transformation.

The history of the rise of the carbide art is an instance in point. The carbides of iron had long been known, and that of aluminium was discovered in the early days of electrometallurgy. Later the investigations of Moissan discovered a series so complete, so varied and yet so interrelated as to rival in theoretical interest any of the organic series. And now a very practical question with metallurgists is how *not* to get a carbide.

Among the abstract of current electrochemical patents in this issue is a description of a patent to Edward G. Acheson, which marks the solution of this problem for the case of aluminium, and perhaps of silicon. Of these, the former is readily obtained in a high state of purity by an electrolytic method, and the latter by any one of several special metallurgical processes. But the simple and brilliant conception that the carbon core of an ordinary electric resistance furnace may be eliminated from the equation, representing the reduction by means of a refractory heat-conducting sheath, and that for this sheath the most refractory carbides possess every essential qualification, seems destined to play an important part in electrometallurgy.

## ELECTROCHEMICAL METHODS IN THE IRON AND STEEL INDUSTRY.

The greater the practical importance of a special field becomes in the development of an industry, and the larger the capital invested in enterprises of such a special field, the greater will be the tendency to differentiation and specialization on the part of the engineers and scientists interested in this special field. This is as it should be. It is a historical fact that the immense industrial developments of recent years were due to differentiation and specialization.

On the other hand, no special industry should lose sight of the development of its sister industries. The development of the whole is always bound to benefit the parts. Therefore, while specialization is the keyword of progress, every progressive engineer and scientist must keep himself informed of the progress in other fields in order to take advantage of it in his own special field.

We are glad to note that Electrochemical Industry, while primarily devoted to the interests of electrochemical engineers and scientists, is also read with steadily-increasing interest by the engineering world in general. In fact, it becomes more and more evident that there is really no branch of engineering which cannot in some way benefit from the recent developments of the art of electrochemistry.

The iron and steel industry has long become of such immense practical importance that it is now considered as a separate industry. There are many books and university courses on general metallurgy in which iron is not dealt with, because, on account of its practical importance, the iron industry is considered as a special metallurgical industry. Nevertheless most of the progress of this industry in recent years has been due to the fact that the most progressive managers and engineers in this field availed themselves of the possibilities offered by the development of other industries.

It is superfluous to speak at length of the wonderful progress which has been made in the iron and steel industry by the introduction of the use of electric power. We may simply refer to some remarks made by Mr. George Westinghouse in a recent speech in London, which was printed in our February issue. As an example, he stated that as a consequence of the progressiveness of the general manager of the Homestead Works of the Carnegie Co. in introducing electric power for any possible purpose, this company produce, with about 4,000 men, three times as much steel as the famous Krupp Works produce with 15,000 men.

The introduction of electric power in iron and steel works may become of immense importance for the introduction of electrochemical methods in such works. When electric current is available, the trial of electrochemical methods becomes an easy matter. The problem of melting iron and making steel in the electric furnace appears to be one of the most fascinating problems of modern metallurgy. Especially abroad, in France and Italy, a number of well-known metallurgists are endeavoring to find an economical solution of the problem. On the other hand, there are many who claim that, in view of the very high economy of the modern blast furnace, there is no danger, in the near future, of the electric furnace superseding the blast furnace. The principal question is, of course, that of cost, and it can readily be seen that the answer to the question whether it would pay to use an electric steel process will greatly depend upon local conditions, upon the cost of power and the cost of fuel. For the present we purposely refrain from discussing the general problem.

What we believe to be most needed at present for an understanding of the problem are facts on electric steel processes actually in operation. Such facts we intend to present to our readers in a series of articles, based directly upon authoritative information given by the engineers in charge of such work. In our January issue we dealt with a French plant using the Keller process; in our February issue we printed an article by Mr. Marcus Ruthenburg on his process, now worked at Lockport, N. Y., and in our present issue we publish an article on the Stassano process, in operation in Italy. We intend to continue this serial in future issues. Of the three processes so far described by us, the Keller process and the Stassano process apply the ordinary electric-furnace methods to the manufacture of steel, while the Ruthenburg process is interesting, as in it magnetic and electric means are combined in a decidedly novel manner to produce the desired results.

While we wish to refrain at present from discussing the principle of the use of electric-furnace methods in the iron and steel industry in general, we may emphasize the great advantages of such methods for the manufacture of special steels, such as tool steels. The present methods of manufacturing such special steels are expensive, and the advantages of electric-furnace methods for this special purpose are evident. It does not appear to be risky to prophesy that it is in this special field that the commercial invasion of electric-furnace methods in the iron and steel industries will be made.

Electric furnace methods are, however, not the only electrochemical methods which will prove of importance in the iron and steel industries. An entirely different example of what electrochemistry can do for these industries is the Goldschmidt "thermite" process of producing high temperatures. The latest developments of this process, with applications to iron and steel, were dealt with in an article by Mr. G. P. Scholl in our January issue. True, the Goldschmidt process is a purely thermochemical process, but it must not be forgotten that it could become of practical importance only after the price of aluminum had been reduced by electrochemical methods. In fact, we have here a special case of the general rule that electrochemical methods enable us to store energy in chemical products, and that the energy thus stored may afterwards be used for other purposes. The calcium carbide and acetylene industry is another example of the same general rule. We may mention in this connection that in recent years calcium carbide has been tried in a similar way as a reducing agent in metallurgical processes. We mention these facts as a proof that the electrochemical methods in the iron and steel industries are not restricted to electric-furnace methods.

## NEW YORK MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The third general meeting of the American Electrochemical Society will be held in New York City, April 16th, 17th and 18th.

Members and guests will please register at the Chemists' Club, 108 West Fifty-fifth street, and receive their badges as soon after their arrival as possible. Badges will be given to all members in good standing and to applicants who have deposited their initiation fee. Special badges will be provided for guests, who must be introduced by a member.

All meetings will be held in the large assembly hall of the Chemists' Club, where members in attendance may have their mail addressed, and where all announcements will be made.

By the courtesy of the Chemists' Club, its club house, including the library of the American Chemical Society, will be open for the use of members and visitors.

By the courtesy of the German Liederkranz, its club house, 111 to 119 East Fifty-eighth street, will also be open to members and guests during the convention. Membership buttons will secure admittance.

On Thursday morning, April 16th, at 9 A. M., a meeting of the Board of Directors will be held, which will be followed, at 10 A. M., by the business meeting of the Society, at which reports of directors and officers will be presented.

Reading and discussion of the following papers: Wilder D. Bancroft, Ph.D., "Constant Voltage and Constant Current Separations;" H. T. Barnes, Ph.D., "Experimental Study of Some Electrode Effects;" J. W. Richards, Ph.D., and W. S. Landis, "The Electrolysis of Water;" Wilder D. Bancroft, Ph.D., "Experiments with Metallic Diaphragms;" C. J. Reed, "Protective Action of Zinc Chloride on Metallic Iron."

At 1 P. M. luncheon will be served at the Chemists' Club, by invitation of the New York members. At 2.30 P. M. reading and discussion of the following papers: Max von Recklinghausen, Ph.D., "Insulating Materials—A Field for Chemists;" H. B. Coho, "A Historical Review of the Storage Battery," with illustrations; Elmer A. Sperry, "The Use of Pyroxyline in Electric Storage Batteries;" W. H. Walker, Ph.D., "The Concentration Changes in the Electrolysis of Brine;" J. W. Walker, Ph.D., "The Influence of Some Impurities in Salt Upon the Yield of Soda by the Amalgam Process;" A. A. Knudson, "The Corrosion of Metals by Electrolysis;" Titus Ulke, "Modern Electrolytic Copper Refining;" N. S. Keith, Ph.D., "A Note on the Composition of Electroplating Solutions;" C. W. Volney, Ph.D., "The Formation of Nitric Acid Under Electric Influences."

At 7 P. M., reception of members and guests in the clubhouse parlors of the German Liederkranz, 111-119 East Fifty-eighth street. At 8 P. M., subscription banquet for members and guests. Ladies are especially invited to participate. The price per cover is $5. A fine musical programme has been arranged.

Friday morning, April 17th, 9.30 A. M., announcement of the results of the election of officers for 1903. Reading and discussion of the following papers: W. D. Bancroft, Ph.D., "Note on Electrical Endosmose;" Louis A. Parsons, Ph.D., "Ions and Electrons;" Carl Hering, "Uniformity in Electrochemical Equivalent;" W. D. Bancroft, Ph.D., "The Electromotive Force of Alloys;" Prof. C. F. Burgess and Carl Hambuechen, Ph.D., "Electrolytic Production of Metallic Compounds;" J. G. Zimmermann, "The Electrodeposition of Metals Upon a Rotating Cathode."

At 1 P. M. luncheon will be served at the Chemists' Club, by invitation of the New York members.

At 2 P. M., excursions to plants and places of interest, as arranged by the Excursion Committee, starting from the Chemists' Club, where detailed notices will be posted.

At 8.30 P. M. the Society will, by special invitation, be the guests of the American Institute of Electrical Engineers at their extra meeting, held in the assembly hall of the Chemists' Club, at which the programme is as follows: President Scott, "Introduction;" W. J. Hammer, "Radium and Other Radioactive Substances, and Certain Phosphorescent and Fluorescent Substances." "The Properties and Applications of Selerium," "The Treatment of Disease by Ultraviolet Rays."

On Saturday morning, April 18th, 9.30 A. M., the following papers will be read and discussed: A. B. Marvin, "Electrolytic Conduction Without Electrodes;" P. G. Salom, "A New Type of Electrolytic Cell;" H. E. Patten and W. R. Alott, "Potentials of Zinc in Aqueous Solutions;" Woolsey McA. Johnson, "Notes on Electrolytic Depositions of Nickel;" Alfred H. Cowles, "What is the Capacity of Molecules for Electric Charge in Electrolysis?" J. A. Steinmetz, "Exhibit of Aluminium Corrosion;" August Eimer, "Exhibit of New Apparatus."

At 1 P. M. luncheon will be served at the Chemists' Club, by invitation of the New York members.

At 2 P. M. excursions will be undertaken to plants and places of interest, as arranged by the Excursion Committee, starting from the Chemists' Club, details of which will be posted.

At 8.30 P. M., meeting in the Chemists' Club, Assembly Hall. Presidential address by President J. W. Richards, Ph.D.; Max von Recklinghausen, Ph.D., Demonstration of the Cooper-Hewitt lamp and rectifier.

At 10 P. M. a German-American smoker (Kneipe) will be held at the Chemists' Club, Assembly Hall, buffet, luncheon, refreshments by courtesy of the New York members. A jolly social evening is assured.

Transportation will be on the certificate plan. All members not residing in New York City should secure certificates when purchasing tickets, in order to get return at one-third rate.

The hotel headquarters of the Society during the convention will be at the Wellington, Seventh avenue and Fifty-fifth street, half a block from the Chemists' Club.

The local committee consists of the following members: Dr. C. A. Doremus, chairman; Alvis von Isakovics, secretary; W. S. Cameron, assistant secretary; G. C. Adams, C. Batchelor, C. S. Bradley, Wm. Hand Browne, Jr., Dr. C. F. Chandler, E. A. Colby, Dr. F. B. Crocker, Dr. G. Drobezy, R. A. Fliess, Dr. H. Foerster-ling, J. C. Hatzel, Dr. N. S. Keith, E. C. Klipstein, A. A. Knudson, Dr. Morris Loeb, W. N. McCoy, C. O. Mailloux, A. Monell, E. H. Mullin, H. N. Potter, Dr. M. von Recklinghausen, E. E. Ries, Dr. S. Sheldon, N. Tesla, W. D. Weaver, E. Weston, C. E. Whitney and Dr. F. G. Wiechmann.

The above elaborate programme shows that the local committee has spared no efforts to insure a full success of the meeting. The attendance promises to be even greater than at the Philadelphia and Niagara Falls meetings.

We are informed that Dr. Walter Nernst, the distinguished professor of electrochemistry at the University of Goettingen, Germany, is expected to be present at the New York meeting.

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## INTERNATIONAL CONGRESS FOR APPLIED CHEMISTRY.

As already noticed in these columns, the Fifth International Congress for Applied Chemistry will be held in Berlin, June 2 to 8, 1903. Section X is devoted to electrochemistry and physical chemistry.

The American committee for this section, as appointed by President Remsen, of the American Chemical Society, consists of Dr. C. A. Doremus, chairman, and Dr. W. D. Bancroft, Dr. C. F. Chandler, Dr. A. A. Noyes and Dr. Edgar F. Smith.

The fee for membership of the Congress is $4.85, and should be forwarded to Dr. H. W. Wiley, chief of the Bureau of Chemistry, Department of Agriculture, Washington, D. C. Members of the Congress are entitled to receive the full printed proceedings of the Congress.

## NOTES ON A CLASSIFICATION OF ELECTROCHEMISTRY.

By Clinton Paul Townsend

### (I) Introduction.

As an art, electrochemistry is remarkable for the wide range of its applications and for its recent rapid growth. To one desirous of keeping abreast of the progress made, and of having at hand a key to the literature of the subject, the question of its classification is a very important one. The classification outlined below deals exclusively with the "art;" that is to say, with the technical applications of the subject, disregarding all matters appertaining solely to the theory. The subject-matter of batteries or electrochemical generators is also excluded, since no useful purpose seems to be served by including this sharply defined and highly complex art under the general title.

The classification was developed, or rather was permitted to develop, during several years, while the writer was serving as examiner of the class of electrochemistry in the United States Patent Office, and in this capacity was mainly engaged in searching and abstracting the literature and the patents with reference to the question of novelty of applications filed. The system is properly referred to as having been permitted to develop for the reason that no effort was made to deliberately subdivide the art into mutually exclusive classes, into which all applications and literature references should be fitted. Such course would obviously be futile, for inventors and writers alike refuse to limit their efforts to the matters so included, but most persistently deal with subject-matter which is essentially marginal, thereby obliterating such divisional lines as may have been established. The course adopted was therefore to segregate from the main subject-matter certain definite classes, made by the inventors and workers themselves, and the limits of which they have shown no tendency to transgress. The classes so divided from the general subject-matter may be clearly kept, and the material not falling clearly into any of them is left to constitute a part of the "general art." From this residual general art it will be found that additional classes segregate in the most natural manner, as the attention of chemists is directed to one or another portion of the field. So, also, as the classes already formed become complex from the number and variety of references contained in them, it is found advisable to divide out as sub-classes the minor subjects wherein especial activity is displayed.

As stated above, matters relating solely to theory are disregarded, but this statement is to be understood as purely relative; for what is pure theory at one stage of the development may be closely related to and interwoven with the technics of a later stage. While the theory is disregarded in the classification proper, it remains as a part of the "general art," to be carried into the appropriate classes as its bearing upon technical progress is made clear. Many instances of this will appear in the following discussion of the classes.

The classification in general outline is essentially, but not exclusively, functional; that is to say, it is based upon methods of work rather than upon apparatus employed. In its subordinate divisions, however, the basis of classification is quite generally the article, compound or element to be produced.

No attempt is made to so define "electrochemistry" as to place any restriction upon the subject matter included. Whatever falls within the limits of the sub-classes is obviously a portion of the art, and whatever bears thereon or possesses any analogy thereto may properly be included in the indices. The classification should be given the utmost elasticity.

The necessities of cross referencing will, in general, be quite apparent. Such classes as "alternating current electrolysis," "colloidal metals" and "organic non-electrolytes in plating" consist largely of cross references taken from the plating classes, and methods of general utility, but specific application, may conveniently be placed under the sub-classes and cross referenced to the general class. As an instance of the latter, an author describes a method for determining the hardness of electrodeposited chromium. The data secured relate to chromium, and are properly included therewith, but the method, being equally applicable to all metallic deposits, is best classed under "aqueous bath."

No claim is made that the outline classification hereinafter given is the best; merely that it has proven in use to be convenient and elastic. The excellent service done for chemists in this country along bibliographical lines will undoubtedly be repeated in the near future for electrochemistry. In fact, several abstract bibliographies of special classes have already appeared. Meantime, however, the necessity devolves upon each electrochemist of arranging such material as he may have at hand in a manner permitting ready reference, and the suggestions here given are offered to this end.

### (II) Classification Outline.

- Electrochemistry.
  - General art.
  - Alternating-current electrolysis.
  - Aqueous bath.
    - Alloys.
    - Aluminium.
      - Deposition on.
    - Anodes.
      - Oxide coatings.
    - Apparatus.
    - Cathodes.
      - Metallizing.
        - Porous substances.
    - Chromium.
    - Colloidal metals.
    - Compounds.
      - Inorganic.
      - Organic.
        - Oxidation methods.
        - Reduction methods.
    - Copper.
    - Osmose.
    - Gold.
    - Haloids.
      - Bleaching and disinfecting liquors.
      - Chlorates.
      - Mercury cathode.
      - Treating cathode lyes.
    - Hydrogen and oxygen.
    - Iron.
    - Lead.
    - Nickel and cobalt
    - Ores.
      - Gold and silver.
        - Cyanides.
        - Halogens.
      - Zinc.
    - Organic non electrolytes in plating.
    - Pickling
    - Pigments.
      - White lead.
    - Platinum and palladium.
    - Reduction by couple.
    - Refining metals
      - Copper.
      - Nickel.
      - Regenerating electrolyte.
    - Silver.
    - Sulphates.
    - Tin.
      - Treating tin scrap.
    - Zinc.
  - Asymmetric conductors.
  - Carbon.

Depolarizing.
Diaphragms.
Electric furnaces.
Electric-furnace processes.
Carbides.
Calcium.
Cyanides and nitrides.
Diamonds.
Graphite.
Oxides.
Phosphorus and phosphides.
Reduction to metal by carbon.
Silicon and silicides.
Sulphides.
Fused bath.
Aluminium.
Sodium.
Magnetism—electrolysis influenced by
Ozone.
Printing processes.
Purifying liquids.
Alcoholic.
Sugar solutions.
Solid electrolytes.
Solvents other than water.
Synthesis.
Oxides of nitrogen.
Tanning.
Vacuum deposits.

(III) NOTES ON OUTLINE.

*General Art.*—This comprises the material not segregated into the classes which follow. It may not inaptly be likened to the complex mother liquor remaining after a series of separations. Discussion of its composition and the relation of residual matter which it contains to the matter separated is best deferred until after the consideration of the several classes.

*Alternating-current Electrolysis.*—This comprises all electrolytic methods based upon the use of an alternating current, irrespective of purpose or conditions. Purely thermal methods are, of course, excluded. The electrolytic alternating-current meters, measuring alternating currents by the loss of weight of electrodes in cells in shunt or induced circuits, are properly classified here, as are also such wave-registering devices as that of Janet. Other examples are the investigations of Sheldon and Waterman upon the sulphating of lead plates, and those of Roepper and Richards upon the production of insoluble sulphides. The synthesis of various organic compounds, pyrocatechin, hydroquinone and urea, fall under this class, as do also the investigations of Maneuvrier and Chappius on the decomposition of water and those of Gerdes and others on the attack of platinum electrodes in ammonium carbonate solutions. The observations of Burgess on the effect of alternating currents superposed upon direct currents in plating operations relate particularly to nickel, and should be classed with this metal, but are properly cross referenced into the present class. These examples and those which follow are not to be considered in any sense as a summary of the contents of the classes. Such summaries, for certain classes possessing particular interest or exhibiting especial activity, it is hoped to offer later. The present effort is rather to illustrate, by means of examples as diverse as possible, the limits of each class. It will be noted that all of the examples given refer to operations conducted in aqueous solution. This limitation is not imposed by the character of the class, but rather by the fact that investigations have not extended to the wider field.

*Aqueous Bath.*—It is partly an accident of development that renders this the most thoroughly studied and fully subdivided of the general classes, and the extent and character of the subdivisions will illustrate how completely the early growth of the art was associated with the study of salts in solution in water. The broad class of aqueous bath as here retained is distinctly *residual*, occupying precisely the position with reference to its sub-classes that the general art does to the art as a whole. The material classified therein is therefore such as is excluded from the sub-classes immediately following. In general, this may be said to comprise (1) data as to the separation of metals whose electrolytic production has not yet become of such technical importance as to warrant their separate classification, or with reference to which investigations hitherto published have touched only the analytical, as distinguished from the industrial side; (2) articles of broader bearing than the limits of any sub-class, typical examples of which are the papers upon the alloying of metals as a factor in electroplating and on the physical character of metal deposits in a recent issue of the ELECTROCHEMICAL INDUSTRY. Other examples are the work of Jordis on the influence of lactic and glycollic acids on the electrodeposition of metals, the abundant literature on the influence of pressure, temperature, etc., upon deposition, and in general any discussion of factors which have a similar or analogous effect in the deposition of more than a single metal; (3) phenomena not related to the plating operation, such, for instance, as the disintegration of metallic cathodes under high current densities and the electrolysis of salts, not otherwise classified, which yield no metallic ion, the idea being to confine the sub-classes designated by the names of metals to plating operations wherein these metals are separated, as metals or as oxides, at one or the other electrode.

FIG. 1.—1,200-AMPERE SWITCH.

Aqueous bath; alloys. The direct deposition of alloys from solutions of mixed electrolytes.

Aqueous bath; aluminium. The deposition of aluminium from aqueous solutions. This sub-class occupies an anomalous position, possessing the extended and confident literature, but being apparently quite innocent of practical achievement.

Aqueous bath; aluminium, deposition on. The peculiar surface of the metal necessitates particular methods of treatment for the formation of adherent deposits of other metals. This sub-class gives evidence of especial activity and substantial recent progress.

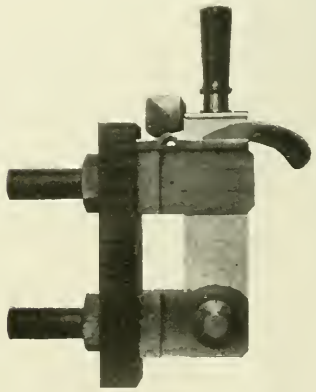

FIG. 2.—1,200-AMPERE SWITCH, WITH SECONDARY ARCING TIP.

Aqueous bath; anodes. The use of an anode is, of course,

common to all methods. This sub-class relates to anode design; their protection at the immersion line; special devices for insuring even current distribution; particular compositions and modes of treatment, and data regarding the life of anodes under specific conditions. The sub-class includes both polarizable and non-polarizable anodes.

Aqueous bath; anodes, oxide coatings. A compact and interesting class, relating mostly to coloring or "browning" iron and steel and the electrolytic imitation of the Russia effect in iron. The separation of metals, as peroxides for analytical and other purposes, not related to the treatment of the anode, is referred to the plating classes.

*(To be continued.)*

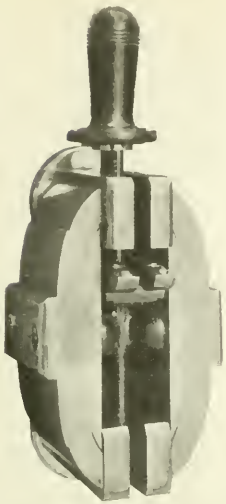

FIG. 3.—3,000 AMPERE 250 VOLT LAMINATED LEVER SWITCH.

## LARGE CAPACITY SWITCHES FOR USE IN ELECTROLYTIC WORK.

By E. M. HEWLETT.

In electrolytic work there are two general methods of connection, the series and the multiple connections. The multiple method of connection necessitates low potential and large current carrying switches, while the series method reduces the current capacity and increases the potential.

The series method is preferable where it is possible, on account of the saving in size of copper conductors and switches. However, in cases where it is necessary to use the lower potentials and large currents, a switch of large capacity and low-contact resistance is required.

FIG. 4.—3,000-AMPERE 250-VOLT LAMINATED LEVER SWITCH.

Considering first the smaller capacity switches, up to 2,000 amperes, the lever type of switch, shown in Figs. 1 and 2, are generally used. These switches are made up with single blades in the smaller capacities, and in the large capacities with two or more blades in parallel. Fig. 2 shows this type of switch with a secondary arcing tip, which is intended to be used where the potential or the character of the load is such as to cause burning at the contacts.

The design is simple, in construction rugged, making a very serviceable switch. Considerable effort is required to operate this type of switch in capacities above 2,000 amperes.

For capacities above 2,000 amperes, and up to 4,000 amperes, the laminated lever type of switch lends itself better, on account of requiring less effort to operate and insuring good contact.

This switch is shown in Figs. 3 and 4, and is made up of a pair of bridging laminated contacts, embracing either side of the contact stud; and the design is such as to insure each individual lamination making separate and positive contact on the stud, thus making an excellent contact of very low resistance.

FIG. 5.—8,000 AMPERE SWITCH.

The laminated lever switches are fitted with secondary arcing tips to take the final break, consequently preventing all roughing of the main contacts due to the arc. These switches are made single, double and triple-pole, single and double throw, and are made in capacities from 1,200 to 4,000 amperes.

In order to make a switch which would operate more easily in larger capacities, the laminated toggle brush switch was designed, as shown in Figs. 5 and 6.

This type of switch is more easily operated for a given capacity than any other, the contacts being of the laminated bridge type and forced in contact under pressure by a toggle. The laminated type of contact is particularly effectual on account of the characteristic of individual contact of the

FIG. 6.—8,000 AMPERE SWITCH.

separate laminations. To insure this positive individual contact it requires a great amount of pressure. The toggle construction makes it possible to obtain this pressure with a minimum effort.

This switch is made in capacities from 2,000 to 12,000 amperes, is fitted with a secondary arcing tip, which protects the main contacts from the effect of the arc on rupturing, and is made single-pole, single, double and triple-throw.

## NOTES ON THE HISTORY OF ELECTROLYTIC COPPER REFINING IN AMERICA.

By Titus Ulke.

In 1879 an experimental plant for refining copper by electrolysis was operated for a short time at Phœnixville, Pa., but the first commercial refinery in America was built by Edward Balbach & Sons at Newark, N. J., early in the 80's.

Up to about 1882 the precious metals were extracted from copper bullion in the United States by the sulphate of copper or vitriolisation process chiefly. With increasing supplies, however, the production very soon exceeded the consumption of sulphate of copper, and the necessity of utilizing another process became more and more obvious. This led to a trial of the electric current for effecting the separation by Messrs. Balbach at Newark, although a previous attempt in this direction, made at Baltimore, had turned out a failure and served as a warning against repetition.

Mr. Balbach, Sr., an excellent practical chemist, and his able son, Mr. Ed. Balbach, Jr., now president of the Balbach Smelting and Refining Co., entrusted Mr. F. A. Thum, a mining and metallurgical engineer, with the task of conducting the experimental work of the new process. The trials proving successful, an electrolytic refinery was erected in 1882-1883 and placed in charge of Mr. Thum, who still ably fills the position of its superintendent.

As it is with almost every case of pioneer work, the difficulties to overcome were many, and discouraging results were frequent at the experimental stage of the process. Under these circumstances, Messrs. Balbach certainly deserve much credit for not relaxing their efforts in continuing the comparatively expensive trials. Owing to the secrecy maintained by English and German refiners, it was next to impossible to obtain working data from them; nor did the patents of James Elkington, the father of electrolytic copper refining, disclose the desired information.

Upon Mr. Thum, therefore, devolved the task of working out the details, such as determining the proper energy of the current required per vat, the arrangement and size of the tanks and of the copper conductors, the way of suspending the electrodes, the production and preparation of the starting sheets and the composition and correction of the electrolyte. As a matter of fact, the rules established and appliances devised by Mr. Thum form the basis of the refining process now in general use, and have been adopted by nearly all American electrolytic copper works.

In those early days there were no voltmeters or ammeters on the market, it appears, and they had to be constructed by each experimenter under the then existing conditions. Apparatus based on the fact that the current from one Daniell cell had a sufficient voltage to drive it through three or four sulphate vats, according to the acidity and temperature of the electrolyte, and that the quantity of the copper deposited in a given time varied directly as the area of the electrodes, and could be increased up to the point where the current-furnishing dynamo began to overheat, at the start served as excellent guides.

The first dynamos used by Messrs. Balbach were furnished by the Excelsior Electrical Co., who were represented by Mr. Wm. Hochhausen, who also assisted in working out the process.

The problem of how to suspend the electrodes and make as perfect a contact with the conductors as possible, while reducing to a minimum the distance between electrodes and allowing the electrolyte to circulate freely, was satisfactorily solved by Mr. Thum by giving the anodes side lugs and their present shape and bending the cathodes over U-shaped suspension bars. At the same time the formula for the proper composition of the electrolyte and a quick and effective way of regenerating it, both of which are in general use to-day, was discovered. Thus, by the end of 1883, all the chief technical points in electrolytic copper refining were satisfactorily settled. The Balbach works, even at that early date, produced from 2 to 3 tons of electrolytic copper daily, but, as this production was soon considered inadequate, they were remodeled until they reached their present tonnage and high state of efficiency.

The refineries at Baltimore, Md., and at Anaconda and Great Falls, Mont., were not started until 1887, 1891 and 1892, respectively. In 1895 the Guggenheim refinery, now known as the Perth Amboy plant of the American Smelting and Refining Co., was built, and in 1898 ground was broken for the erection of the great Raritan Copper Works, Perth Amboy, N. J., and the current turned on in the tank house March 23, 1899, after an interval of less than eight months.

The 50-ton De Lamar electrolytic works were started March 14, 1902, and the new 100-ton tank house and equipment at the Perth Amboy plant (Guggenheim works), arranged according to A. L. Walker's improved design, were put in commission last year.

Sixteen years ago the Balbach and the Bridgeport, Conn., works were the only large electrolytic plants in America, and their output was less than 24 short tons of copper per diem. Yet to-day there are in operation ten electrolytic refineries, producing the enormous quantity of 705 tons daily, or about 257,000 tons of copper annually, besides over 25,000,000 ounces of silver and 318,000 ounces of gold.

## REDUCTION FACTORS FOR ELECTROLYTIC DEPOSITS.

By Carl Hering.

As there are quite a number of different units or quantities in terms of which the amounts of substances reduced or formed electrolytically are expressed, it often becomes necessary or desirable to change from one unit to another. While many of these reductions from one to the other are comparatively simple, yet they always involve some labor and introduce the possibility of making an error. To avoid this, and to show at a glance what relations the units bear to one another, the following table of reduction factors has been calculated under the direction of the writer, and will often be found to be quite useful.

The table gives the value of each unit in terms of each of the others into which it is likely to be converted, so that in any case only one multiplication is necessary. Moreover, the reciprocal values are also given in most cases in their proper places, thus avoiding all long divisions. Approximate values have also been added, which are correct within 2 per cent., and are therefore sufficiently accurate for most practical purposes. These approximate numbers have been so chosen that they involve the least possible figuring, generally only a multiplication by a single digit, a division by another and sometimes the pointing off of some decimal places. This requires even less figuring than a multiplication by a value given in only two figures, which involves three rows of figures and an addition. Moreover, the error in using only two-figure values is variable, and may be as high as 10 per cent., while with these approximate values it is always within 2 per cent.

The figures are not a compilation, but have all been re-calculated from the legal weights and measures of this country (and with a very slight difference of Great Britain also), as used by the National Bureau of Standards in Washington. They have been carefully calculated and subsequently checked, and it is believed there are no errors. They are given in the order of

size. The year in the larger commercial units was taken as 365¼ days.

It will be noticed that there are a number of unsuspectedly simple and easily-remembered relations between a number of these units. For instance, 5½ pounds per day are almost exactly a ton (of 2,000 pounds) per year, or 5½ kilograms per day are equal to 2 metric tons per year. Every gram per minute is about 3 pounds per day, or nearly 1½ kilograms per day. A ton per year is about 134 grams per minute. A metric ton per year is about 6 pounds per day, or ¼ pound per hour. Other similar relations may readily be found from the table:

1 pound (av.) per year *(lb./yr.)* equals:
0.002738 pound per day.—Aprx. 11/4 ÷ 1,000.
0.0008624 gram per minute.—Aprx. 6.7 ÷ 1,000.

1 kilogram per year *(kg./yr.)* equals:
0.006036 pound per day.—Aprx. 6 ÷ 1,000.
0.002738 kilogram per day.—Aprx. 11/4 ÷ 1,000.
0.001901 gram per minute.—Aprx. 19 ÷ 10,000.

1 gram per hour *(g./hr.)* equals:
1/60 or 0.01667 gram per minute, which see for other values.

1 milligram per second *(mg./sec.)* equals:
0.00 gram per minute, which see for other values.

1 pound (av.) per day *(lb./day)* equals:
365.25 pounds per year.—Aprx. 11 3 × 100.
165.7 kilograms per year.—Aprx. 1 6 × 1,000.
2/3 or 0.6667 ounce per hour.
0.4530 kilogram per day.—Aprx. 9 2 ÷ 10.
0.3150 gram per minute.—Aprx. 31 ÷ 100.
0.1826 ton (net) per year.—Aprx. 11 6 ÷ 10.
0.1657 metric ton per year.—Aprx. 1/6.
1/24 or 0.04167 pound per hour.
0.01890 kilogram per hour.—Aprx. 19 ÷ 1,000.

1 ounce (av.) per hour *(oz./hr.)* equals:
3/2 or 1.5 pounds per day.
0.6804 kilogram per day.—Aprx. 68 ÷ 100.
0.4725 gram per minute.—Aprx. 14 3 ÷ 10.

1 kilogram per day *(kg. day)* equals:
805.2 pounds per year.—Aprx. 800.
365.25 kilograms per year.—Aprx. 11 3 × 100
0.6944 gram per minute.—Aprx. 7 10.
0.4026 ton (net) per year.—Aprx. 4 10.
0.36525 metric ton per year.—Aprx. 11 3 ÷ 10.
0.00186 pound per hour.—Aprx. 1/11.
1/24 or 0.04167 kilogram per hour.

1 gram per minute *(gr. min.)* equals:
1159.5 pounds per year.—Aprx. 7 6 × 1,000.
525.96 kilograms per year.—Aprx. 1 19 × 10,000
60 grams per hour.
100/6 or 16.67 milligrams per second.
3.175 pounds per day.—Aprx. 32 10.
1.44 kilograms per day.—Aprx. 10 7.
0.5800 ton (net) per year.—Aprx. 4 7
0.5260 metric ton per year.—Aprx. 10 19
0.1323 pound per hour.—Aprx. 4 3 ÷ 10.
0.06 kilogram per hour.

1 ton (net) per year *(ton yr.)* equals:
5.476 pounds per day.—Aprx. 11 2.
2.484 kilograms per day.—Aprx. 10 4
1.725 grams per minute.—Aprx. 7 4.
0.2282 pound per hour.—Aprx. 9 4 ÷ 10
0.1035 kilogram per hour.—Aprx. 31 3 ÷ 10.

1 metric ton per year *(t. yr.)* equals:
6.030 pounds per day.—Aprx. 6.
2.738 kilograms per day.—Aprx. 3 11 × 10
1.901 grams per minute.—Aprx. 19 10.
0.2515 pound per hour.—Aprx. 1/4.
0.1141 kilogram per hour.—Aprx. 8 7

1 pound (av.) per hour *(lb. hr.)* equals:
8766. pounds per year.—Aprx. 7 8 × 10,000
3970. kilograms per year.—Aprx. 4,000.
10.89 kilograms per day.—Aprx. 11.
7.500 grams per minute.—Aprx. 3 4 × 10.
4.383 tons (net) per year.—Aprx. 4 9 × 10.
3.976 metric tons per year.—Aprx. 4.

1 kilogram per hour *(kg. hr.)* equals:
19,325 pounds per year.—Aprx. 19,000.
8,760 kilograms per year.—Aprx. 7 8 × 10,000.

1 kilogram per hour *(kg. hr.)* equals:
52.91 pounds per day.—Aprx. 53.
100/6 or 16.67 grams per minute.
9.663 tons (net) per year.—Aprx. 29/3 or 3 3/31 × 100.
8.760 metric tons per year.—Aprx. 7 8 × 10.

1 ounce (av.) per minute equals:
3¾ pounds per hour, which see for other values.

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## EQUIPMENT OF AN ELECTROMETALLURGICAL LABORATORY.*

BY R. S. HUTTON AND J. E. TEAVEL.

In considering the equipment of a laboratory for experimental work in electrometallurgy, the point of utmost importance should be, in the first place, to provide power to enable the experiments to be carried out on a reasonably large scale. The actual magnitude of the power equipment must be regulated by two principles. It is very desirable that the experiments, though not on a scale directly comparable with the commercial process, should nevertheless be of sufficient magnitude to furnish reliable practical data. On the other hand, as the question of cost has, unfortunately, to be considered, it is necessary to keep the equipment within certain limits, so that any given experiment can be repeated frequently under all possible conditions. Such work will supply not only valuable scientific information, but also the necessary data for practical application.

Having said thus much with regard to the scale of the work, let us consider what should be the main points governing the choice of equipment. The variety of different forms of electric furnaces which have been proposed or used is extremely great, and it would be altogether impossible to provide in any laboratory, however large or wealthy, even the most important of these. With regard to the generating plant, the same may be said. In commercial work we find conditions varying from the 15,000-volt nitric acid plant down to the 4 or 5 volts required by the zinc or aluminium processes; from the continuous current used in all electrolytic work to the polyphase alternating current employed in the purely electro thermal reactions.

Our object, therefore, must be not to establish a limited number of definite examples, but to obtain an equipment extremely flexible, so that, without serious expense, any of the conditions required by such work may be obtained. It is, unfortunately, rarely possible to turn an ideal into a concrete fact. The development of a laboratory must necessarily be gradual, each year bringing alterations and improvements. Nevertheless a description of the actual equipment of the electrochemical laboratory of Owens College may be of some value to those interested in the subject, either from a commercial or theoretical point of view. The motive power at present available is rather insufficient, but hopes are entertained that it may before long be increased. It consists of a gas engine and dynamo, which can be coupled onto the same driving shaft, and together are capable of developing a net output of 30 to 40 kw. The generating plant comprises several different types of machines.

One unit of 10 kw is capable of being connected so as to give any electromotive force between 10 and 200 volts, the maximum current being 600 ampères. This dynamo is used for arc fur-

* This is one part of a paper read before the Manchester section of the British Institution of Electrical Engineers. Mr. R. S. Hutton, who visited this country last year and read a paper on the fusion of quartz in the electric furnace at the Niagara Falls meeting of the American Electrochemical Society [Electrochemi al Industry vol. I. p. 58] is in charge of the electrochemical laboratory of Owens College, Manchester. In the other parts of their paper the authors give notes on technical processes, mainly those used at Niagara Falls, which have already been fully discussed in ELECTROCHEMICAL INDUSTRY.—Ed.

[illegible] work. Finally, a dynamo specially intended for electrolytic work, consisting of [illegible] amperes at 15 volts. With regard to alternating currents, a 40-kw three-phase and a 20-kw single-phase motor are provided. The latter can be connected so as to give anything between 30 amperes at 600 volts and 250 amperes at 72 volts. Finally, plant used some time ago by Mr. McDougall for the manufacture of nitric acid was presented by him to the laboratory. It will give alternating current up to 10,000 volts.

Passing now from the dynamo house to the electrochemical laboratory itself, the first problem is the exact regulation of

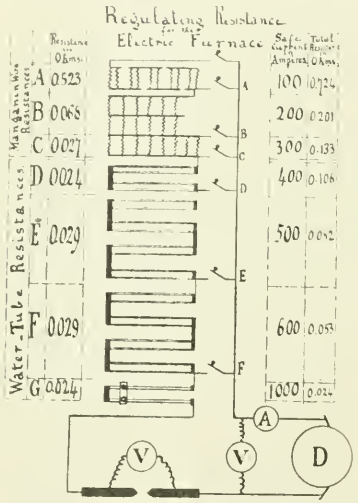


FIG. 1.—REGULATING RESISTANCE FOR ELECTRIC FURNACES.

these comparatively large currents, since, for satisfactorily studying some of the electrolytic processes, it is absolutely essential to have the current entirely under control. The diagram of the series resistance used for this purpose is shown in

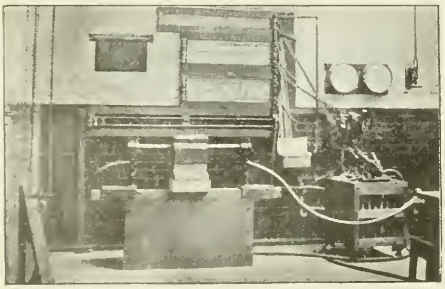

FIG. 2.—REGULATING RESISTANCE FOR 40 KW MOISSAN FURNACE.

Fig. 1. As will be seen, a number of switches are provided, by means of which successive portions may be short-circuited. Frames A, B, C are manganin wire resistances, and, together with the corresponding switches, are mounted on a stand fitted with rollers. The other frames consist of German silver tubes, fixed permanently to the wall and provided with a water circulation. D is made of $\frac{1}{4}$-inch tubes, about 4 feet long and 0.025 inch thick; E and F of $\frac{1}{4}$-inch tubes, 3 feet long and 0.03 inch thick, whilst G is of $\frac{1}{2}$-inch tubes, 6$\frac{1}{2}$ feet long and 0.02 inch thick.

This resistance is divided into two parts, the first of manganin wire, designed particularly for starting an arc furnace, and capable of being used for currents up to 300 ampères; the second consisting of German silver tubes, water cooled, and with maximum carrying capacity of 1,000 ampères. After some consideration, the water-tube resistance was chosen as being the most suitable for regulating large currents,* and, as this subject is of some general interest, we venture to give details of the design and of the behavior under actual working conditions. The design of the water-tube frames is shown in Fig. 2, which gives a general view of the frames, and Figs. 3 and 4 give detail of the design of the terminal pieces. Fig. 2

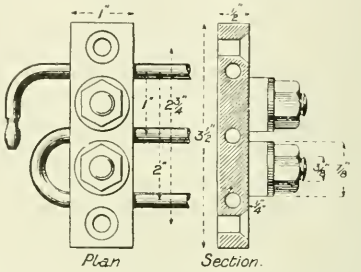


FIG. 3.—TERMINALS OF WATER-TUBE RESISTANCE (600-AMPERE FRAME).

shows the regulating resistance for a 40-kw Moissan furnace. To the right is the portable resistance, and above the 500, 600 and 1,000-ampère short-circulating switches. Bare copper strips, 1$\frac{1}{4}$ x $\frac{1}{4}$ inch and 2 x $\frac{1}{4}$ inch, connect these switches with the different frames seen in the center. The two carbons are carried in massive copper holders, which can be adjusted to any given height, the leads being bolted to the vertical standard of the holder of 2$\frac{1}{4}$ square inches cross section.

The frames are of two types, the first being made of parallel $\frac{1}{4}$-inch tubes for currents of 600 ampères and below. As will be seen, these tubes are let into $\frac{1}{2}$ x 1-inch gun-metal strips, which are fixed onto wooden frames; each strip carries two $\frac{1}{8}$-inch set screws, serving as terminals. One of these is used for the permanent leads, the other is useful to fix any temporary connection. The second type of frame for 1,000 ampères consists of two $\frac{1}{2}$-inch German silver tubes, 6$\frac{1}{2}$ feet long, connected in series, and has a resistance of 0.024 ohm.

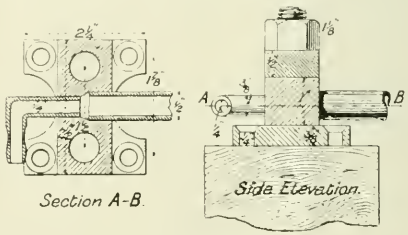


FIG. 4.—TERMINALS OF WATER-TUBE RESISTANCE (1,000-AMPERE FRAME).

The terminals shown in Fig. 4 are similar to those just described, but more massive. Two sliders are provided, of the design shown in Fig. 5, by which the actual resistance in circuit can be varied and the current adjusted with accuracy to the value desired.

As will be seen, there is a stiff central spring, by means of which the sliders are kept in contact with the tubes during adjustment. They can be clamped in any given position by two thumb screws. In considering the maximum power which

* See also *Zeitschr. für Elektrochemie*, vol. 8, p. p. 6, 58, 123, 124 (1902).

may be dissipated in a water tube resistance, we are concerned with two principal factors. Firstly, the maximum rate at which water can be passed through the tubes; secondly, the maximum rate at which heat can be transmitted from the metal to the water. In all practical cases the first limiting factor will intervene long before the second would show its influence. The design of the water-tube frame will therefore depend on the dimensions of the tube and the available head of water. As a general guiding factor, we may say that a flow of 1 liter per minute will dissipate up to $2\frac{1}{2}$ kw.

The larger tubes are distinctly the more satisfactory, since in this case there is no difficulty in obtaining an efficient flow of water from the ordinary supply. With the smaller tubes it

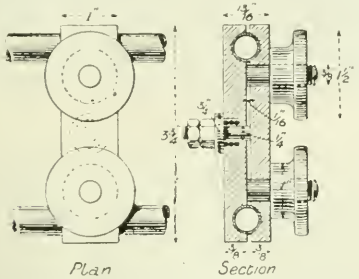


FIG. 5.—SLIDES FOR 1,000-AMPERE WATER-TUBE RESISTANCE.

is necessary to have numerous inlets and outlets, as their resistance to the flow of water is considerable.

Close to the water tubes a resistance is provided by which the exciting current of any of the dynamos can be most effectively regulated. It is in constant use for the considerable variations of voltage necessary during the progress of some of the furnace operations.

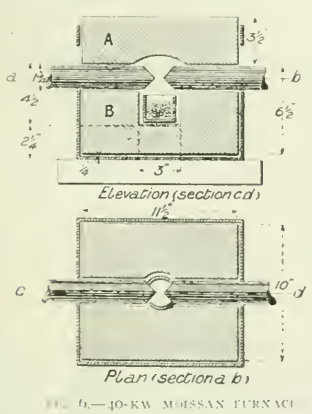


FIG. 6.—40-KW MOISSAN FURNACE.

We now come to the actual furnace equipment and the different types of apparatus which are best adapted for laboratory work. Foremost amongst these must be placed the Moissan furnace.* A dimensioned drawing of this type for a power of about 40 kw is given in Fig. 6.

This is constructed of blocks of Monk's Park bath stone, which, after trials with various limestones, has proved to be the most suitable. The furnace is composed of two blocks, the first, A, forming the cover, the second, B, the furnace proper. This latter has two grooves of slightly greater diameter than the carbons to be used. As the blocks are apt to split under the influence of the heat, they are held together by iron bands. These are provided with sockets (not shown in figure), which enable the furnace or cover to be lifted by long iron bars. The central hole, which may be of diameter $2\frac{1}{2}$ to 4 inches, according to size of crucible in use, is lined at the bottom by a layer of powdered magnesia, which prevents the carbon crucible coming in direct contact with the lime. An annular space should be left around the crucible, which not only facilitates the heating, but also prevents the lime and carbon from entering into combination.

Taking into consideration the many discoveries made by Moissan in the course of his investigations, it is surprising that as yet only a very small percentage have found commercial application. The reason of this may perhaps be ascribed to the fact that this form of furnace, though proving itself eminently suitable for the pioneering work for which it was intended, scarcely gives any data on which a technical process could be founded. It is, in fact, a striking example of how the apparatus most suited for purely scientific work is seldom capable of direct commercial application. It was not until the work was taken up by the practical engineer that the scientific discovery developed into a commercial industry.

Most frequently the financial success of a process has been in direct proportion to the mechanical improvements introduced, the chemical modifications being generally of secondary importance. It is therefore necessary to be able to provide a type of

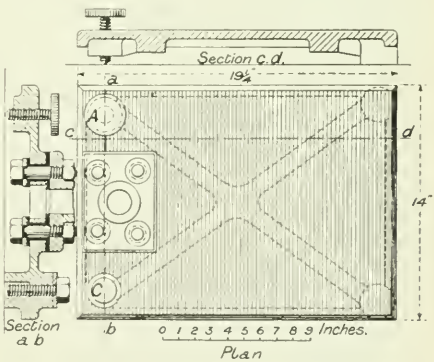


FIG. 7.—VERTICAL ELECTRIC FURNACE PLAN.

furnace corresponding in principle to the most usual technical forms, and thus carry out the experiments; if not on the same scale, at least in the same manner as would be done in the factory. Fig. 7 is a plan of an apparatus similar to that used by Haber,* which we have found extremely useful for representing many different forms of furnace. The apparatus consists of a cast iron base, an adjustable standard and a feeding gear. The base is $\frac{1}{2}$ inch ruling thickness, strengthened with ribs and cross ribs 1 inch thick. At one corner a $\frac{3}{4}$-inch bolt C serves as a terminal. A is a leveling screw. The square base of the standard is insulated by a slab of vulcanized fibre, and held down by four $\frac{3}{4}$-inch bolts. See section A-B.

Fig. 8 is the vertical furnace elevation. A hollow cast-iron column R, $2\frac{1}{2}$ inches diameter, is fixed onto the base shown in the previous figure, but insulated from it. The height of the gun-metal cross bar carrying the screw feeding gear can be adjusted within wide limits by means of the $1\frac{1}{4}$-inch steel rod S, which is clamped in position by the hand wheels A and B. Connection can be made at either of the terminals K or E (the latter for currents above 600 amperes), the opposite pole being connected to the base. To avoid sliding contacts, which would be objectionable for such large currents, connection from the cross bar to the screw carrying the carbon rod is made by means of four $\frac{1}{2}$-inch flexibles, not shown in this figure, but which can be clearly seen in Fig. 9. The gun-metal rod T, which carries the carbon is $1\frac{1}{2}$ inches diameter, with a square

* Moissan, *Le Four Electrique*, Paris, 1897.

* Haber, *Zeitschr. fur Elektrochemie*, vol. 8, pp. 1, 26, 60 (1902).

screw thread (four threads to the inch), giving a feed of about 1 foot. It is raised or lowered by means of a 7-inch cast-iron hand wheel. The design of the carbon holder is clearly shown. It is provided with rings of various diameter,

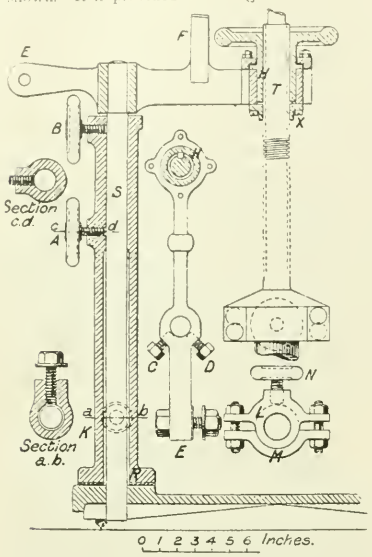


FIG. 8.—VERTICAL ELECTRIC FURNACE ELEVATION.

so that carbons of very different sizes up to 3 inches can be held.

Fig. 9, A, shows one way in which the vertical furnace, the design of which is shown in the previous figures, can be used. Upon the cast-iron base which forms the negative pole is

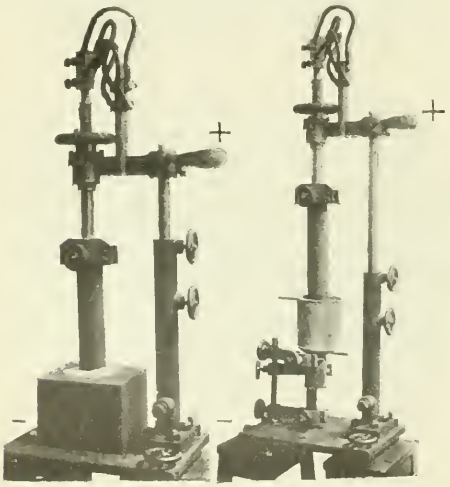


FIG. 9A. ELECTRIC FURNACES. FIG. 9B.

placed a large block of carbon, having a cavity which serves as a crucible. The positive electrode is formed by a carbon 3 inches in diameter, which is fed by the screw gear described above.

In Fig. 9, B, the apparatus is fitted to be used for the electrolysis of fused salts. The water jacket, by causing a layer of the fused mass to solidify, enables the electrolyte itself to form the crucible lining. This is frequently necessary, since

FIG. 10.—40 HP. CARBORUNDUM FURNACE.

with many substances it is impossible to find a furnace material capable of withstanding their corrosive action at the high

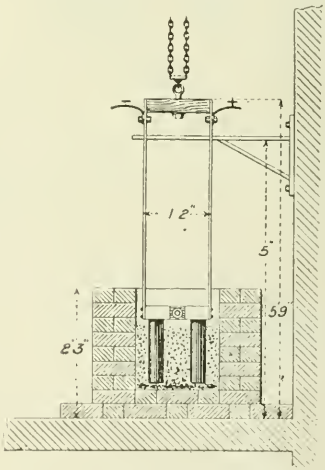


FIG. 11.—40 KW EXPERIMENTAL CARBIDE FURNACE.

temperatures which prevail. The negative pole is in this case formed by a vertical carbon, which is held in a clamp sliding on a gun-metal vertical rod fixed to the base.

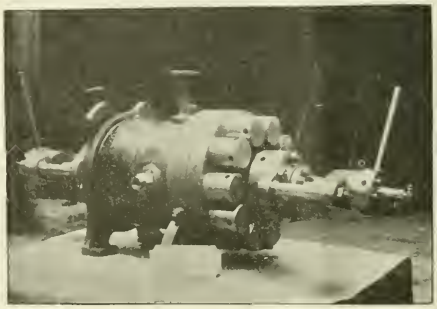

FIG. 12.—HIGH PRESSURE APPARATUS.

Connected as shown in Fig. 9, A, the furnace has proved

itself most satisfactory for the manufacture of aluminium by the electrolysis of cryolite containing $Al_2O_3$. Replacing the carbon block shown in this figure by a small furnace built of loose bricks, a good example of a carbide "pot" furnace, giving a most satisfactory yield of calcium carbide, can be obtained. Frequently in the electrolysis of fused salts it is an absolute necessity to make the crucible lining of the material itself. This result is obtained (as shown by Muthmann, Hofer and Weiss)* by the use of a water-cooled crucible. The arrangement is shown in Fig. 9, B. Whilst the vertical holder enables us to represent a large number of different types of furnace, those of the Acheson carborundum type can be very simply built up by the use of ordinary materials.

Fig. 10 shows a carborundum furnace as used with 40 hp. This is an almost exact reproduction of the commercial furnace on a small scale. It is built up of loose fire bricks on a cast iron base, the outside dimensions being 46 inches long, 28 inches broad and 21 inches high. The electrodes, consisting each of two graphite plates, $2^1/_2 \times 1$ inch, are in contact with coke, which also forms the core connecting the two. This is a resistance furnace of type E, shown in Fig. 13. The core is surrounded by the mixture of sand, coke, sawdust and salt, from which the carborundum is made.

The next figure (Fig. 11) is a drawing of a furnace suitable for making calcium carbide or for other furnace operations. The design is inexpensive, and the apparatus most serviceable. It represents a satisfactory and convenient laboratory form of many and important technical furnaces. The two carbons, which are clamped side by side in a single holder, but insulated one from another, are raised and lowered by means of a crane fitted to the wall. The current is led in by flat copper bars, which, by sliding in grooves, prevent any oscillation or side motion of the apparatus. The body of the furnace consists either, as shown in the figure, of fire bricks or of a large cast-iron pot. In both cases the material itself forms the actual lining.

* *Liebig's Annalen*,—vol. 320, pp. 231—269 (1902).

Such experimental equipment will be of importance not only from an educational point of view, but it is by no means impossible that certain of the difficulties in technical processes may be overcome by its use.

It is important, however, not to neglect the purely scientific work, which, though it may possibly not find any direct application in the immediate future, has, however, frequently proved to be the starting point of notable advances. In this direction the work in progress consists in the determination of the effect of gaseous pressure on high-temperature chemical phenomena. It is proposed to study carefully some of the gaseous and other reactions, which may be expected to differ considerably from those occurring under ordinary conditions.

The apparatus shown in Fig. 12 is destined for work up to 200 atmospheres and for currents up to 1,000 amperes, and has been provided out of funds received from the Government Grant Committee of the Royal Society. The apparatus is practically a steel inclosure, placed either horizontally or vertically, which can be used for any of the different types of furnace. It is air-tight, and designed for a working pressure of 200 atmospheres, being tested at 500 atmospheres. On the right and left will be seen the screw gear by which the carbons are fed, whilst in front and behind are windows which will stand the full pressure, but which can be replaced by additional connections when a circulation of gas through the apparatus is desired. The main valve, which serves also to connect the pressure gauges, will be seen on the top. The apparatus is water-jacketed throughout, the refractory material of which the furnace proper is made being contained in a cast-iron lining, thus insuring the protection of the main forging. The construction of this apparatus has been carried out by Messrs. Lennox, Reynolds and Fyfe to the designs made at the college.

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Science Abstracts.—Our well-known contemporary, *Science Abstracts*, will in future be published in two sections: A, physics, including chemical physics and electrochemistry; B, engineering, including industrial electrochemistry.

## SOLID ELECTROLYTE CELLS.

By A. L. Marsh.

Previous to the year 1885 there had not been made a voltaic cell with a solid electrolyte which, at ordinary temperatures, could generate even the smallest appreciable electric current. Sir William Thomson, now Lord Kelvin, found that when warm glass was placed between plates of zinc and copper an electromotive force was indicated by an electrometer connected with the metals. Professors Ayrton and Perry extended the observation to the cases of paraffine wax, gutta percha, india rubber and shellac. But with electrolytes of such high resistance no current could possibly be generated of sufficient strength to be indicated by the most delicate galvanometer.

On June 27, 1885, Shelford Bidwell exhibited to the Physical Society a cell with plates of silver and copper, and having for electrolyte a mixture of one part of copper sulphide (CuS) with five parts of sulphur. When connected with a reflecting galvanometer, this cell produced a current which moved the spot of light off the scale.

The electromotive force of the cell was found to be .07 volt, and the internal resistance 6.537 ohms. Upon attempting to reduce this resistance by diminishing the proportion of free sulphur, the electromotive force gradually diminished as the proportion of sulphur was decreased, until the voltage became 0, when only copper sulphide was present—at least no appreciable current was given. Copper was the positive pole of this cell.

Bidwell reasoned that the sulphur owed its efficiency to the fact that silver sulphide is formed on the silver plate by direct combination. He therefore constructed the following cell: A thin layer of copper sulphide was spread upon a copper plate and compressed into a compact mass against a surface of polished steel. A layer of silver sulphide was then spread upon the copper sulphide, and the cell was completed by pressing a plate of silver upon the silver sulphide. The current which this cell produced through the shunted galvanometer was considerably greater than that from the cell first described.

The cell was still not satisfactory. There seemed to be indications of short-circuiting, which Bidwell thought might be due to the penetration of particles of copper sulphide through the layer of silver sulphide. The silver plate was removed from the cell, and its surface brushed over with a dilute solution of sulphur in bisulphide of carbon. The plate was then heated over a gas flame, and was soon covered with a uniform and continuous layer of silver sulphide, the heating being continued until all the free sulphur was volatilized. The cell constructed with this prepared plate produced a current of 6,800 microampères through an external resistance of .2 ohm, and was able to deflect the pivoted needle of an ordinary galvanometer. The dimensions of the cell were as follows: The plates were 2 x 2½ inches; the thickness of the two layers of strongly-compressed sulphides was about one-twentieth of an inch. The electromotive force was .053 volt. The internal resistance was therefore about 7 ohms.

Carhart's "Primary Batteries" and Benjamin's "Voltaic Cell" give a brief description of the above cell. They state the electromotive force to be .5 volt, which is evidently a mistake. The correct value is .05 volt.

This cell seems to be exactly analogous to the Daniell cell.

Copper, copper sulphide, silver sulphide, silver (Bidwell cell).

Copper, copper sulphate, zinc sulphate, zinc (Daniell cell).

Bidwell adds that silver is probably the best (or only) possible metal for the positive plate.

Later Bidwell constructed a cell of lead and metallic sodium for the two plates, with lead peroxide for the electrolyte. This combination gave a very powerful current. No figures were given.

The writer undertook a brief study of solid electrolyte cells in the spring of 1900. The first experiments were a repetition of those of Shelford Bidwell with the sulphides of silver and copper, and gave results closely agreeing with those obtained by Bidwell as to the electromotive force produced in each case. The measurements were made with a reflecting galvanometer and condenser. The following combinations were then tried:

Copper, mixture of copper phosphide and red phosphorus, zinc.

Copper, mixture of copper phosphide and red phosphorus, sodium.

Copper, arsenic (metallic), sodium.

The copper phosphide was prepared by mixing pure sponge copper, obtained by electrolysis of a copper sulphate solution, with red phosphorus in the proper proportion to form the compound $Cu_3P_2$. The mixture was slowly heated in absence of air until combination took place, which is indicated by a slight explosion. By washing this product with a dilute solution of potassium bichromate, to which a little sulphuric acid is added, and afterward with distilled water, a procedure recommended by Boettger, a quite pure product of copper phosphide ($Cu_3P_2$) is obtained.

For one set of experiments, a mixture of coper phosphide and red phosphorus was taken for the electrolyte, and compressed between a piece of metallic sodium and a sheet of copper, and the whole kept under a light oil. The electromotive force was found to be about 1.5 volts, and the resistance was less than 100 ohms per square inch of contact surface. The electromotive force did not materially increase when the percentage of phosphorus in the mixture was increased to about 75 per cent., but the resistance became much greater.

By substituting zinc for the metallic sodium in the above combination, the electromotive force of the couple becomes about .8 volt. A cell prepared in a glass tube three-eighths of an inch in diameter gave a sufficiently strong current to move the mercury column of a not very delicate Lippman electrometer.

The arrangement of the cell is shown in the figure. The zinc is used in the form of an amalgam, of such a consistency that it can be poured into the cell when hot and cools to a rather solid paste. The mixture of copper phosphide and phosphorus is pressed in over the zinc amalgam, and a disk of copper is pressed firmly over the mixture. The connection to the zinc amalgam was made by a platinum wire, which was sealed into the glass. The materials used were carefully dried before putting into the cell, and the completed cell kept in a desiccator over sulphuric acid.

The following experiment was tried: A small lump of metallic arsenic was pressed against a slab of sodium, and the whole covered with a light oil. Each metal had a thin copper wire connected to it. An electromotive force of 1.2 volts was shown by a potentiometer. On another trial a copper-arsenic-sodium couple gave at the start an electromotive force of .05 volt. The cell was allowed to stand on closed circuit with 1,000 ohms external resistance. The electromotive force steadily increased, and at the end of ten days had reached .3 volt.

It is a difficult matter to get the materials absolutely free from water, but, granting that in the experiments described above there was a trace of water present, we should hardly expect the comparatively low resistance shown by solid electrolyte cells to be due to the pressure of water, since the materials are practically insoluble in water. However, the small number of experiments performed does not admit of any positive conclusions being drawn.

This class of cells has so far been but little studied, but it is to be hoped that the importance of these cells, from a scientific point of view, will induce others to take up their study. The work of the writer along this line was cut short, and facilities for its continuance are not yet available.

Owing to their rather high resistance, solid electrolyte cells will probably find little practical use. It is possible that they may be used as standards of electromotive force, but so little has been done in the study of this type of cell that their adaptability to this work is uncertain.

## STEEL PRODUCTION IN THE ELECTRIC FURNACE.

Dr. Goldschmidt, the well-known inventor of the Goldschmidt process, last year received a commission from the German Patent Office to go to Italy and investigate a Stassano electric furnace which was in practical operation, in order to ascertain whether it was really possible to manufacture iron in this furnace, containing less than .2 per cent. of carbon. He had occasion, during several days, to study the process in detail, and to take samples of the raw materials and finished products for analysis. The following is an abstract from a paper about the process, read by him before a recent meeting of the Electrochemical Society of Cologne.

The plant is situated at Darfs, to the north of the dago d'Tseo. The most essential feature of the Stassano process consists in the direct reduction of the iron ores by charcoal, in combination with the heat radiated by an electric arc working above the charge. At the same time undesired compounds in the ore are slagged off by means of suitable fluxes. Large carbon rods are introduced from opposite sides into a shaft furnace, constructed of masonry, with a working chamber 1 x 1 x 1 meter, lined with magnesite bricks. They carry alternating current of about 2,000 ampères at 170 volts, and their distance from each other, which is small at the beginning of the operation, is gradually increased as the temperature rises, until the arc travels through the whole width of the furnace with a tremendous cracking and hissing noise. The electric plant is represented by two dynamos of 500 horse-power each, and one dynamo of 100 horse-power, driven by water-power.

Table No. 2 shows more exactly the working of the process in a smaller furnace, which Dr. Goldschmidt also had occasion to observe. The extraordinary purity of the iron produced by this process is due in a great measure to the purity of the Italian iron ores which were used. Suitable fluxes are added, which throw nearly all the silicon, and a considerable amount of manganese, sulphur and phosphorus, into the slag. Table No. 1 shows the composition of the charge in a case which was very closely observed, and also gives a thermo-chemical calculation of the process. Table No. 3 shows the thermic result and the calculation of the cost of production for a ton of iron under the local conditions.

TABLE NO. 1.

*Composition.*

| *Of the ore used.* | *Of the fluxes.* |
|---|---|
| $Fe_2O_3$ = 93.02 per cent. | CaO = 51.21 per cent. |
| MnO = 0.619 per cent. | MgO = 3.11 per cent. |
| $SiO_2$ = 3.79 per cent. | $Al_2O_3$ } |
| S = 0.058 per cent. | $Fe_2O_3$ } = 0.5 per cent. |
| P = 0.056 per cent. | $SiO_2$ = 0.9 per cent. |
| CaO } | |
| MgO } = 0.5 per cent. | $CO_2$ = 43.43 per cent. |
| $H_2O$ = 1.72 per cent. | |
| *Of the coal.* | *Of the charge.* |
| C = 90.42 per cent. | Ore = 100 kgs |
| Ash = 3.88 per cent. | Coal = 23 kgs |
| $H_2O$ = 5.70 per cent. | Flux = 12.5 kgs |
| *Of the iron produced* | *Of the additions.* |
| Fe = 99.764 per cent. | C = 50.2 per cent. |
| Mn = 0.092 per cent. | Hydrocarbons 40.5 per cent |
| Si = per cent. | Ash = 0.27 per cent |
| S = 0.059 per cent. | |
| P = 0.009 per cent. | |
| C = 0.090 per cent. | |

*Of the charge per 100 kgs ore.*

| | |
|---|---|
| $Fe_2O_3$ = 93.02 kg | ore. |
| MnO = 0.619 kg | |
| $SiO_2$ = 3.79 kg | |
| S = 0.058 kg | |
| P = 0.056 kg | |
| CaO } | |
| MgO } = 0.5 kg | |
| $H_2O$ = 1.72 kg | |
| C = 20.9 kg | coal. |
| Ash = 0.892 kg | |
| $H_2O$ = 1.21 kg | |
| CaO = 6.401 kg | fluxes. |
| MgO = 0.389 kg | |
| $SiO_2$ = 1.125 kg | |
| $Al_2O_3$ } | |
| $Fe_2O_3$ } = 0.062 kg | |
| $CO_2$ = 5.429 kg | |

THERMO-CHEMISTRY OF THE PROCESS.

*General.*

Coal, 7,500 cal
With 20 per cent. efficiency, 1,500 cal
1 hp.-hour = 653.3 cal
With 80 per cent. efficiency, 508.24 cal
Therefore, effect of 1 kg coal = effect of 3 hp. hours.
There are used:
For the decomposition of 1 gram mol $Fe_2O_3$, 192.000 cal
For the conversion of 1 kg water of 100° into steam of 100°, 637.000 cal
For the heating of 1 kg steam of 100° by 1°, 0.480 cal
For the calcination of 1 kg of flux, 425.000 cal
For the heating of 1 kg mol $CO_2$ for 1°, 0.016 cal
For the heating of 1 gr mol $Co_2$ for 1°, 0.0068 cal
For the melting of 1 kg of iron, 350.000 cal
For the melting of 1 kg of slag, 600.000 cal
By the combustion of 1 kg C to CO there are generated 2,175.000 cal

*Special.*

There are used:
For the decomposition of the oxide of iron, 93.02 × 192 ÷ 0.16 = 111,552.000 cal
For the evaporation of water from ore and coal, (1.72 + 1.21) × 637 = 1,866.41 cal
For the heating of the water vapor to 500°, 2.93 × 0.048 × 400 = 562.56 cal
For the calcination of the fluxes, 12.5 × 425 = 5,312.5 cal
For the heating of the $CO_2$ to 500°, 5.429 × 0.016 × 500 ÷ 0.044 = 987.09 cal
For the heating of the generated CO, 20.9 × 0.0068 × 500 ÷ 0.012 = 5,021.667 cal
For the melting of the iron produced, 65 × 350, 22,775.2 cal
For the melting of the slag, 13.89 × 600, 8,334.0 cal
Total, 157,311.427 cal
By the combustion of C to CO are generated, 20.9 × 2175, 45,457.5 cal
Difference, 111,853.927 cal

111,853.927 cal at 80 per cent. efficiency = 219.08 hp hours, or, as 65,114 kgs of iron are produced, per kilo of iron = 3.364 hp hours. One ton of iron, therefore, would cost in electric power at 0.0057 lire per hp hour = 19.17 lire or 15.34 marks, or about $3.83. Cost of one developed electric horse-power, 300 lire.

Yearly costs: 10 per cent. interest and depreciation, 30 lire; maintenance, 10 lire; total 40 lire, 32 marks, or about $8.

One hp hour costs, therefore $\frac{1.00}{1.000}$ = 0.0057 lire = 0.45 pfennig, or about 0.11 cent

TABLE NO. 2.

Example of an operation (in the small furnace, with 1,000 ampères and 80 volts):

Charge, 70.25 kgs, ore mixture of the following composition:

| | |
|---|---|
| Iron ore | 1,000 |
| Limestone | 125 |
| Carbon | 160 |
| Additions | 120 |

Product obtained, 308 kgs wrought iron.

The charge contained in this operation:

| | |
|---|---|
| 46.51 kg $Fe_2O_3$ | from ore. |
| 0.309 kg MnO | |
| 1.895 kg $SiO_2$ | |
| 0.25 kg CaO + MgO | |
| 0.86 kg $H_2O$ | |
| 3.263 kg CaO | from fluxes. |
| 0.194 kg MgO | |
| 0.056 kg $SiO_2$ | |
| 0.031 kg $Al_2O_3$ + $Fe_2O_3$ | |
| 2.714 kg $CO_2$ | |
| 7.234 kg C | from coal. |
| 0.310 kg Ash | |
| 0.456 kg $H_2O$ | |
| 3.552 kg C | additions. |
| 2.43 kg hydrocarbons | |
| 0.016 kg ash | |

Properties and quantity of the materials:

| Substances | Charged gr. | Obtained gr. |
|---|---|---|
| Fe | 32,557.29 | 30,727.312 |
| Mn | 239.745 | 28.336 |
| Si | 910.448 | traces |
| S | 29.000 | 15.172 |
| P | 28.000 | 2.772 |

Progress of the operation:

At 8.15 the charge commences and current is put on. At 9.15 charging is finished, and at 10.15 casting takes place. The current is regulated in such a way that, after twenty minutes, the voltage is 80 and the current 800 ampères. After a further twenty minutes 100 volts and 1,000 ampères are put on, and after thirty minutes the voltage is reduced to 70 and the current to 600 ampères. After thirty minutes more the voltage is reduced to 50 and the current to 500 ampères, and during the last twenty minutes 100 volts and 1,000 ampères are used. The total energy equals 7,200,000 volt-ampère minutes, which, at a power factor of 0.8 equals 97,200 watt hours, or 132.24 horse-power hours.

TABLE NO. 3.

Final thermic result:

| | Calories. |
|---|---|
| For the reduction of the resulting Fe are necessary $30{,}727.312 \times 192 \div 112 =$ | 52,730.262 |
| For the reduction of the Mn contained in the product are necessary $28.336 \times 94.6 \div 55 =$ | 48.719 |
| For the melting of the metal, $30.8 \times 350 =$ | 10,780.000 |
| For the melting of the slag, $6.3 \times 600 =$ | 3,780.000 |
| For the evaporation of the water and its conversion into steam of 100°, $1.316 \times 637 =$ | 838.292 |
| For the burning of the lime, $6.25 \times 475 =$ | 2,968.75 |
| For the superheating of the water vapor to 500°, $1.316 \times 400 \times 0.48 =$ | 252.672 |
| For the superheating of the $CO_2$ to 500°, $2.714 \times 500 \times 0.016 \div 0.044 =$ | 493.451 |
| For the superheating of the hydrocarbons to 500°, $2.43 \times 500 \times 0.27 =$ | 328.05 |
| For the superheating of the CO generated in the reduction of Fe and Mn $\left(3 \cdot \frac{30{,}727.312}{112} \cdot \frac{28.336}{55}\right) \cdot 500 \cdot 0.0058$ | 2860.131 |
| Total | 75,020.330 |

Heat generated by the combination of the charged C to CO during the reduction, $9.883 \times 2{,}175$ .... 21,495.525

Difference ..... 53,524.805

Therefore, as the heat furnished $= 132.24 \times 635.3 =$ 84,012.072 calories, the thermic efficiency is 61.33 per cent.

Calculation of the cost for 1,000 kg iron in a plant of 5,000 hp, producing 30 tons of steel in twenty-four hours (about 66⅔ per cent. thermic efficiency):

| | Lire. |
|---|---|
| 1,600 kg ore, at 15 lire | 24.00 |
| For pulverization of the ore, at 3 lire | 4.80 |
| 200 kg flux, at 5 lire | 1.00 |
| 250 kg cokes, at 45 lire | 11.25 |
| For pulverization of the coke, at 2 lire | 0.50 |
| 190 kg additions, at 70.0 lire | 13.30 |
| For making the mixtures, at 3.0 lire | 6.75 |
| Wear of electrodes 12 kg, at 0.30 lire | 3.60 |
| Maintenance of the furnace | 12.00 |
| Wages | 6.00 |
| Utensils | 3.00 |
| Electric power, 4,000 hp hours at 0.0057 | 22.80 |
| Incidental costs | 3.00 |
| Total | 112.00 |
| Minus volatile and combustible gases obtained, 900 cub. met. at 2 ent | 18.00 |
| Remainder, actual cost | 94.00 |

Equal to 75.2 marks, or about $18.8

TABLE NO. 4.

Composition of iron and steels produced in the Stassano furnace directly from the ores:

| | | |
|---|---|---|
| C = 0.04 per cent. | C = 0.04 per cent. | C = 0.17 per cent. |
| Mn = 0.05 per cent. | Mn = 0.12 per cent. | Mn = 0.07 per cent. |
| C = 0.09 per cent. | C = 0.77 per cent. | Si = trace |
| Mn = 0.18 per cent. | Mn = 0.65 per cent. | P = 0.029 per cent. |
| Si = trace | S = 0.04 per cent. | S = 0.05 per cent. |
| | Chromium steel: | |
| | C = 1.51 per cent. | |
| | Mn = 0.26 per cent. | |
| | Cr = 1.22 per cent. | |

TABLE NO. 5.

Chemical composition of Italian ores:

| Magnetic. | Red Hematite. |
|---|---|
| $Fe_3O_4$, 78.400 per cent. | $Fe_2O_3$, 88.850 per cent. |
| MnO, 0.700 per cent. | MnO, 0.470 per cent. |
| $SiO_2$, 8.650 per cent. | $SiO_2$, 2.060 per cent. |
| $Al_2O_3$, 7.330 per cent. | $Al_2O_3$, 3.420 per cent. |
| CaO, 2.100 per cent. | CaO, 0.870 per cent. |
| MgO, 1.030 per cent. | S, 0.078 per cent. |
| S, 0.055 per cent. | P, 0.093 per cent |
| P, 0.068 per cent. | Loss on ignition, 2.561 p. c. |
| Limonite. | Limonite. |
| $Fe_2O_3$, 80.030 per cent. | $Fe_2O_3$, 73.840 per cent. |
| MnO, 0.567 per cent. | MnO, 0.567 per cent. |
| $SiO_2$, 1.070 per cent. | $SiO_2$, 1.070 per cent. |
| $Al_2O_3$, 2.152 per cent. | $Al_2O_3$, 2.152 per cent. |
| CaO, 0.590 per cent. | CaO, 0.590 per cent. |
| P, 0.124 per cent. | P, 0.124 per cent. |
| S, 0.070 per cent. | S, 0.070 per cent. |
| Loss on ignition, 12.630 p. c. | Loss on ignition, 15.550 p. c. |

The surprising result is gained that, by using water-power, the ton of iron can be produced for about $18.8. The item of only 3 lire for incidental costs appears, however, too small. Anyway the result of the closely watched experiment teaches that this method of producing iron and steel can come into consideration everywhere where cheap water power and pure ores etc. enter into the question. Besides Italy, Chile [illegible]

comes into consideration, and the Chilean Government has sent a representative to study the process thoroughly.

Dr. Goldschmidt came to the conclusion that, for Germany, the process could not compete with the usual metallurgical method of producing steel. For crucible steel, however, the case might be different. Eventually the process might be used in such a way that ordinary pig iron were refined in the Stassano furnace. But extended experiments are still necessary to prove such a possibility.

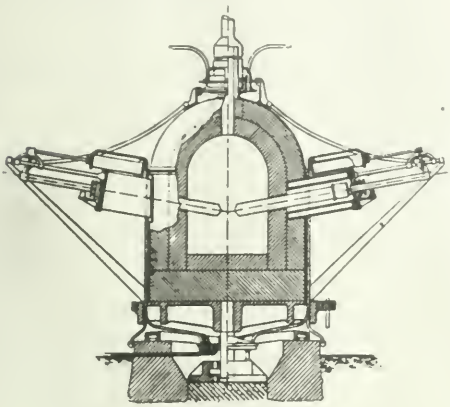

FIG. 1.—STASSANO FURNACE.

In any case, this is a method which has passed the first experimental stage, and merits serious consideration and attention. It cannot be omitted, however, to state that for the installation on a large scale a good deal of money will have to be paid yet for experience, as the Stassano works in Italy have already had about 1,000,000 lire sunk into them without having, up to this time, taken up manufacturing on a large scale. One of the drawbacks there has been that Stassano has no skilled

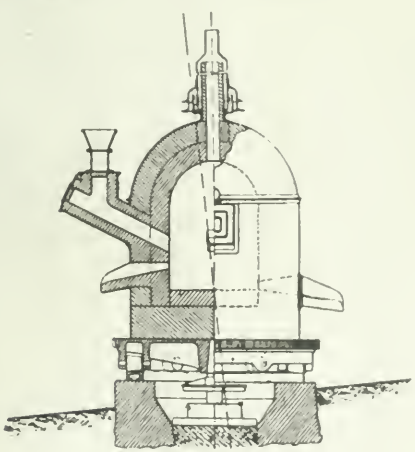

FIG. 2.—STASSANO FURNACE.

men whatever, and has to be, in fact, his own machinist, laborer, furnace man and chemist, so that he merits the greatest praise for his extraordinary zeal and tenacity in reaching the goal which he set himself.

From the above detailed figures and tables it is pretty evident that the calculations are based upon the local conditions of Italy, and that for other countries the results of the calculations would be quite different. For this reason we have given Dr. Goldschmidt's tables and calculations in full, so that our readers are enabled to recalculate the cost of the process for different conditions.

The latest form of the Stassano furnace is shown in the accompanying illustrations. Fig. 1 is a cross section of the furnace through the plane of the electrodes, and Fig. 2 is a cross section at right angles to Fig. 1. It will be noticed that the furnace is arranged for being revolved around a vertical axis. The arrangement for drawing the electrodes apart during the operation of the furnace is also plainly visible in the figures.

## SOCIETY OF ELECTROCHEMISTS AND METALLURGISTS.

The new British Society of Electrochemists was successfully inaugurated on February 4th at the general meeting held at St. Ermin's Hotel, London. After a few introductory remarks had been made by the president of the British Institution of Electrical Engineers, Mr. James Swinburne, the formal motion that the Society be formed was moved by Mr. Joseph Swan, F. R. S., and seconded by Mr. Alexander Siemens. It was stated that similar organizations for the promotion of electrochemical science and practice had been in existence for a considerable time both in Germany and the United States. The seriousness of adding to the already very great number of existing scientific societies had been keenly felt by the provisional committee, but up to the present, at any rate, owing to the peculiar nature of the sciences of electrochemistry and electrometallurgy, no satisfactory *modus vivendi* had been arrived at for affiliation with an existing organization. The following council was unanimously elected:

President, J. W. Swan; vice-presidents, Prof. A. Crum-Brown, Lord Kelvin, Sir Oliver T. Lodge, Dr. Ludwig Mond, Lord Rayleigh, Alexander Siemens and James Swinburne. Council, George Beilby, Bertram Blount, A. J. Charleton, W. R. Cooper, Sherard Cowper-Cowles, Dr. F. G. Donnan, Prof. A. K. Huntingdon, Dr. R. A. Lehfeldt, Dr. W. S. Squiere, Dr. O. J. Steinhart. The honorable secretary is F. S. Spiers, 82 Victoria street, S. W., London.

CARNEGIE INSTITUTION GRANTS.—The Carnegie Institution, through President Gilman, formerly president of Johns Hopkins University, has made five grants of money to Johns Hopkins men to assist original researches. Two of these were announced by President Remsen lately, as follows: To, Dr. Harmon N. Morse, professor of analytical chemistry, $1,500 for an assistant in his researches upon the new method he has evolved for measurement of osmotic pressures. Dr. J. B. Whitehead, in the physical department, has received a liberal grant to carry forward a research in the theory of the magnetic field developed by Maxwell..

PRODUCTION OF ZINC BY ELECTRICITY.—United States Consul Bergh sends from Gothenburg the translation of an article recently published by a local newspaper on experiments made by Dr. De Laval on the production of zinc from the ore by electricity at the factory Önan, belonging to Trollhattans Elektriska Aktiebolag, Trollhättan. It is reported that the manufacture of carbide at Önan has been discontinued and the production of zinc by Dr. De Laval's method adopted. An expert states: "Dr. De Laval has for several years worked on the problem of producing zinc by electricity from lead-sulphur-zinc ores. He was probably led to this by his experiments in trying to separate iron from ores by electricity. An examining board has reported favorably on the method, and the result has been the organization of a company to exploit the invention and the ore deposits at Saxberget, near Ludvika. The minimum capital—$256,800—has already been paid, and the company will start operations as soon as circumstances will allow."

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl.

## Electric Furnaces and Furnace Products.

*Method of Reducing Metallic Oxides.* Edward G. Acheson, Niagara Falls, N. Y. Patent No. 718,891, January 20, 1903. Application filed December 4, 1900.

*Electric Furnace.* Edward G. Acheson, Niagara Falls, N. Y. Patent No. 718,892, January 20, 1903. Application filed December 20, 1900.

In these patents Mr. Acheson describes a method for the production of metals in an electric furnace, heated by means of a core of carbon. On account of reactions taking place between the reduced metals and the carbon of the core, with the production of carbides, it has hitherto been impossible to obtain pure metals in that way. It has been proposed to prevent the metals from coming into contact with the carbon core by means of an intervening layer of inert materials, such as clay, corundum, etc. This has been more or less unsatisfactory, on account of

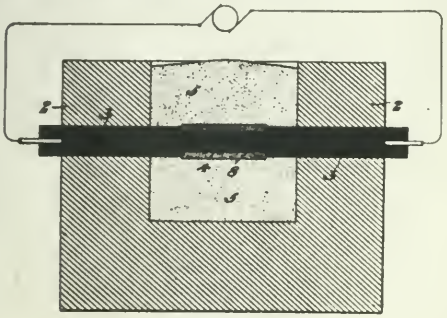

Fig. 1.—Acheson furnace.

their melting at high temperatures or undergoing reactions with the core. It is now proposed by Mr. Acheson to form this intervening protecting layer out of a refractory carbide, preferably carborundum, which is stable at the highest temperatures employed for metallurgical reactions, and does not react any more with the carbon of the core. In the manufacture of substances such as silicon or boron, which form refractory carbides, a granular carbon core is simply surrounded with the material to be reduced, mixed with carbon in proper proportion to accomplish the reduction. On passing a current through the core, the material adjacent to it combines with it to form a carbide, *i. e.*, a carbide of silicon if sand has been used in the charge. This layer of carbide incloses the core and protects it from contact with the charge. The remainder of the charge is then heated by radiation, and the metal obtained from it in a fused state by the reducing action of the carbon mixed with the charge. When the conductor is not formed of carbon granules, or where it is not desired that the core should be wasted in the formation of the carbide, a layer of the oxide to be treated, mixed with carbon in proper proportion to form a carbide, is placed around the core, and the first heating action of the current converts this layer into carbide. When the material to be reduced is alumina or another material whose metal does not form a refractory carbide, either a mixture of carbon with the oxide of silicon, boron, etc., in such proportions as to form a carbide, is placed around the core, or the core is surrounded by a layer of a finely-powdered, previously-formed carbide, such as carborundum, etc. This latter procedure is preferred, on account of the property possessed by such carbides of cohering to a dense mass of good heat conductivity. The current may be either direct or alternating, and a direct current of 30 or more ampères per square inch of cross section of conductor, when the conductor is granular, and greater when the conductor is composed of rods or plates, may be employed. The operation is carried on in a furnace, shown in Fig. 1, where 2 represents the walls of the furnace, 3, 3 the terminals of the dynamo circuit, 4 the carbon core, 8 the protecting layer of carbide and 5 the body of the charge mixture. The reduced metal will collect at the bottom, and may be tapped out or removed as a pig at the end of the operation.

*Electric Furnace.* H. N. Potter, New Rochelle, N. Y. Patent No. 719,507. February 3, 1903. Application filed November 21, 1901. Divided and filed again November 20, 1902.

The specification describes a modification of a former patent by the same inventor, abstracted in Electrochemical Industry, January, 1903, page 187. It has the same object, namely, to provide means for preventing the current to flow unevenly in electric tube furnaces, by reason of almost unavoidable slight differences in the specific resistance of the tube, due to structural, and perhaps chemical, irregularities in the tube material. The tube is composed of a mixture of magnesia and alumina, and is provided with a number of pairs of terminals. Each pair of confronting terminals is connected to a ballast resistance, which tends to maintain an even distribution of the current from all the terminals.

*Apparatus for Electro-thermally Treating Materials.* Hudson Maxim, London, England. Patent No. 719,484. February 3, 1903. Application filed August 17, 1898.

The invention relates to a furnace for the manufacture of carbides. It consists of two stationary end walls, between which is situated a crucible of fire clay, mounted on wheels, which can easily be removed. Two or more pairs of electrodes enter through one of the end walls. They are made movable, and at the beginning of the operation extend through the furnace until they touch a conductor, consisting of calcium carbide in plate form, arranged on the opposite end wall of the furnace. This conductor will provide a body of highly incandescent material to start the operation of the furnace, and as the furnace charge enters into reaction between the electrodes, they are gradually withdrawn towards the other end wall of the furnace. In this way a continuing incandescent conductor is provided, and by the time the electrodes have reached the front wall, the furnace is filled with a slab of carbide. When the electrodes are drawn out entirely, the crucible is removed and the carbide allowed to cool, while another crucible, filled with fresh charge, is put into place. Means for cooling the electrodes by a series of tubes, built in the end wall of the furnace and connected with a supply of cold water, are also described.

*Electric Furnace.* John F. Hammond, New York, N. Y. Patent No. 720,024. February 10, 1903. Application filed February 1, 1902.

The invention relates to electric furnaces for dentists' use in continuous-gum work and other work requiring a high temperature for baking. The object of the invention is to utilize the heat to the best possible advantage, and to provide for the inspection of the work without exposing it to injurious drafts. Another object is to simplify the construction and facilitate repairs, and to provide for convenient handling of the work. A furnace embodying the above principles is described in detail.

*Method of Subdividing Ingots or Blocks of Carbide.* Joseph Scales, Niagara Falls, N. Y. Patent No. 719,882, February 3, 1903. Application filed May 6, 1902.

This invention consists in a method for the subdivision of blocks or ingots of such carbides which react with water, particularly for detaching large pieces of calcium carbide from ingots formed in carbide furnaces. One or more holes are drilled into the body of the ingot while it is still very hot, and at the same time water or steam is injected into the cavity, preferably through the drill. By this means the cutting surface of the drill is preserved, and the drilling operation is facilitated on account of the local disintegration of the carbide by the steam. A wedge is then driven into the drill holes and blocks of the desired size broken off.

*Process of Making Tap-hole Plugs.* Andrew Dickey, Niagara Falls, N. Y. Patent No. 718,828, January 20, 1903. Application filed December 2, 1901. Divided and re-filed October 31, 1902.

The invention covers the process of making such tap-hole plugs as are described by the inventor in his patent No. 714,159, abstracted in ELECTROCHEMICAL INDUSTRY, January, 1903, page 189. The plugs are designed for use in carbon-lined furnaces, and are made from compressed sawdust, paper pulp or similar material, with or without the addition of a glutinous or similar binder.

## APPARATUS FOR THE ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

*Recovering Tin from Scrap.* R. U. Gould, Surbiton England. Patent No. 718,927, January 20, 1903. Application filed August 27, 1900.

The process consists of two stages. In the first stage the major part of the tin is removed from the tin scraps by making them the soluble anode of a galvanic cell. The electrolyte is sea water or brine, and a cathode of carbon or a mixture of carbon, with a depolarizer like pyrolusite, etc., is employed. The construction of the cell comprises a vessel, in which is placed a wicker basket, inside of which is arranged a similar basket of smaller diameter. The annular space between the wicker baskets is filled with the tin scraps, and a cylindrical carbon cathode is placed in the middle of the vessel. In some cases it is preferred to dispense with the wicker baskets and to pile the tin scraps around a number of tinned iron bars, serving as conductors and arranged in a circle around the cathode. The iron of the scraps is said to go into solution as chloride of iron, while the bulk of the tin precipitates on the cathode and part goes into solution as chlorides of tin. In order to remove the last thin layer of tin from the scraps, they are subjected to the second stage of the process, which is purely electrolytic. They are transferred to vessels similar to the above and electrolyzed by a current furnished by the cell of the first stage in an electrolyte of caustic soda. The scraps are made the anode, and a tinned iron plate serves as cathode. An elaborate example of the working of the process is given, in which vessels 6 x 6 x 6 inches served as galvanic cells, while a vessel 3 x 3¼ x 5¼ inches was used as electrolytic cell. There is nothing said about tests of installations on a practical scale.

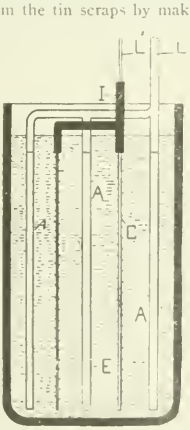


FIG. 2.—REED ELECTROLYTIC APPARATUS.

*Electrolytic Apparatus.* Charles J. Reed, Philadelphia, Pa. Patent No. 719,870, February 3, 1903. Application filed May 5, 1899.

The invention has for its object to improve the construction of amalgamated cathode plates, used in the deposition of highly electropositive metals, such as sodium, potassium, zinc, etc., in such a way as to retain the mercury on their surfaces and to prevent its tendency to work gradually downward. The means adopted consist in providing vertical plates of copper or other suitable metals with a number of horizontal grooves, serving as a receptacle for the mercury. The apparatus, shown in Fig. 2, consists of a glass or hard rubber jar J, filled with an electrolyte, *i. e.*, sulphate of zinc. The anodes A may contain the metal to be operated upon, or they may consist of platinum, lead, carbon, lead peroxide, etc. The cathode C, of copper, is provided with a series of horizontal grooves, containing mercury. The metal deposited on the plate is amalgamated, as it draws the mercury out of the grooves by capillary attraction. On re-dissolving the precipitated metals, either by connecting the cathode plate with an anode of peroxide of lead or by passing a current in the opposite direction, the liberated mercury returns to the grooves. The term "electrolytic apparatus," as used in the specification, is intended to cover also storage batteries.

*Electrolytic Apparatus.* Charles J. Reed, Philadelphia, Pa. Patent No. 719,871, February 3, 1903. Application filed May 5, 1899.

This invention is intended to facilitate the depositing action of apparatus used for the deposition of highly electropositive metals, as sodium, potassium, cadmium or zinc, and to prevent the formation of arborescent crystals. It has been found that if such metals be deposited on an amalgam of mercury and a metal nearly as electropositive as the metal to be deposited, instead of on a plate of amalgamated copper or other highly electronegative material, that the character of the deposit is entirely changed and the growth of arborescent crystals prevented. In order to obtain the best results, it is necessary that the amalgam be in the form of an incoherent mass or paste, and for this reason a mechanical support is provided, for which purpose copper has been found well suited. The cathode of the apparatus consists of a copper plate, either wholly or partly covered with the amalgam paste. The discharge of the deposited metal takes place as above.

*Electrolytic Apparatus.* Charles J. Reed, Philadelphia, Pa. Patent No. 719,872, February 3, 1903. Application filed May 5, 1900.

This specification shows several constructions of cathode plates, with the same object in view as in patent No. 719,870. Receptacles of hard rubber, shown cylindrical in form, are filled with mercury, and the lower edge of the plates projects into them through a slot in the top. The plates may also be vertically divided by means of slots, and in this case a separate mercury receptacle is provided for each section. The plates may be smooth, or they may have vertical capillary grooves.

*Electrolytic Apparatus.* Charles J. Reed, Philadelphia, Pa. Patent No. 719,873, February 3, 1903. Application filed May 5, 1899.

This invention relates to the same subject as the preceding one, and its object is to subdivide the cathode plates into a number of divisions or panels, and to provide each panel at its lower edge with a separate receptacle for mercury, so as to insure uniform amalgamation. The frame supporting the panels is protected from electrolytic action by an insulating cover, in order to prevent a loss of mercury. A large number of different constructions are shown, having rectangular, oblong and polygonal panels, with the object of facilitating the collecting of the mercury.

*Apparatus for Electroendosmotically Freeing Materials from Fluids.* Botho Schwerin, Berlin, Germany. Patent No. 720,180, February 10, 1903. Application filed April 24, 1902.

This invention relates to an improved apparatus for the process of electroendosmotically freeing mineral, vegetable and animal substances from water and other fluids, covered by the inventor in patent No. 670,350. It has been found that the thickness of the layer of material subjected to the process is of great influence, and, in the case of the treatment of peat pulp, a layer above 50 centimeters in thickness entirely prevented satisfactory results. The present apparatus, therefore, provides for the subdivision of the material into a number of small layers, to be acted upon simultaneously. To this end, the apparatus is constructed of a frame work, furnished with five corrugated metal shelves, one above the other. Wooden boxes, open at the top, having a double wire netting at the bottom and filled with the material to be treated, are put upon these shelves. The netting serves as cathode, and iron plates, resting on top of the material, serve as anodes. Means are arranged by which the anodes can be simultaneously lifted, in order to remove or insert the boxes. The water, driven out from the material by the action of the current, collects in the grooved bottoms and is drawn off. It is stated that, by connecting three apparatuses, each consisting of five shelves, each shelf receiving two anodic boxes 5 cm high, 90 cm long and 80 cm wide, in series to a 225-volt dynamo, 40 to 50 per cent. of water have been removed from peat sludge in three hours, the system requiring at the beginning a direct current of about 4 amperes, decreasing to 2½ amperes at the end.

*Electrolytic Diaphragm, and Process of Making Same.* Hugh Rodman, Philadelphia, Pa. Patent No. 720,741, February 17, 1903. Application filed March 18, 1902.

The process of making this diaphragm consists in mixing three parts of para rubber, two parts of sulphur and fifteen parts of finely-powdered potassium sulphate, and rolling the mixture out to a sheet one-sixteenth of an inch thick. This is molded and vulcanized at a temperature of 300° F. for about ten hours, taking particular care to have this heat dry. It is then soaked in running water for four or five days thus dissolving all potassium sulphate. The resulting product is suitable to be used in the decomposition of brine.

*Process of Recovering and Separating Metals from their Ores.* Hans A. Frasch, Hamilton, Canada. Patent No. 720,235, February 10, 1903. Application filed November 2, 1900.

This process is an improvement upon the inventor's former one, and is said to be particularly applicable to the treatment of copper-nickel ore and matte. The electrolytic plant proposed to carry the process into effect is illustrated in Fig 3. Any number of baths may be aranged at progressively lower levels. Each bath has in its bottom a perforated feed pipe 7 and discharge pipe 8, and an electric conductor 9, surrounded with a quantity of coarsely-disintegrated matte 10, which forms the anode. This matte is covered with a layer 11 of sand or other chemically inert granular material. Cathode plates 12 are suspended in the upper portion of the bath. Tank 14 supplies bath 2 with brine by means of pipe 13, and bath 2 overflows into tank 15, whence the brine can be raised through pipe 16 and lifting apparatus 17 into tank 18, to be returned to bath 2. By this means circulation can be accomplished. Between each two baths is arranged an automatic regulator 19, 20, 21, 22, 36. This regulator serves to adjust the overflow of the anode and cathode solution by means of their relative specific gravity. The current decomposes the brine solution in bath 2 with the production of caustic soda at the cathodes, while a chloride solution is formed in the anode compartment by the chlorine acting upon the matte. The chloride solution leaves bath 2 through pipe 29 and regulator 19, passing through pipe 32, through the anode compartment of bath 4, etc., until, from regulator 36, it flows into tank 39. The lifting apparatus 41 delivers the metallic solution, which may have been previously acidified to increase its conductivity, from tank 39 into the cathode compartment of bath 3, the baths 3, 4, 5 and 6 having been previously filled with salt brine or metallic salt solution from previous operations. The electric current is now closed between poles 42 and 43, so that the whole series of baths is in one circuit. The least positive of the metals in the chloride solution from tank 39 is deposited on the cathodes of bath 3. The copper is precipitated in the next and the following baths, as many as are necessary to precipitate it completely. The electrolyte then flows into tank 33, where it is treated with oxidizing agents and carbonate of lime, for the purpose of removing the iron. After the removal of the iron, the electrolyte is delivered by the lifting apparatus 35, through pipe 34, into the cathode compartment of bath 6, where the nickel is deposited. The electrolyte from bath 6 flows through the cathode compartments of as many baths as are required to remove the nickel, and finally, through regulator 36, into bath 37, whence it may be returned to tank 14 and used over again for circulation. Whenever the electrolyte contains enough cobalt or metals more electropositive than nickel, the latter may be removed in the same manner as the copper and nickel in an additional number of similar baths.

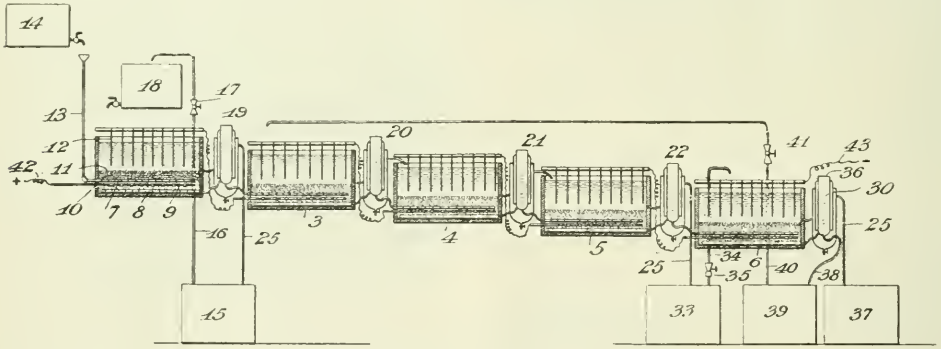


FIG. 3.—FRASCH PROCESS FOR TREATING NICKEL MATTE.

*Apparatus for Decomposing Water by Electrolysis.* W. F. Mason McCarty, Rockyridge, Md. Patent No. 721,068, February 17, 1903. Application filed April 22, 1902.

The apparatus consists of two tanks, connected by a pipe at about half their height. Each tank contains an electrode, which are so located that their upper ends are about in a line with the axis of the connecting pipe, through which the current passes from one tank to the other. Each of the two tanks has an outlet at the top, through which the gases generated may be led to suitable holders.

## STORAGE BATTERIES.

*Accumulator Plate.* Wilhelm Kraushaar, Neumuehl, Germany. Patent No. 718,774. January 20, 1903. Application filed June 20, 1902.

The inventor claims "an accumulator plate consisting of a lead plate, with thin ribs or strips on both sides thereof, which are divided by cuts, characterized by the fact that the cuts which divide the ribs into several parts are opposite to a point between the cuts in the adjoining strips, and that the parts of two neighboring ribs are united by ribs of equal height similarly arranged to the cuts, with the object of increasing the effective surface and to sufficiently stiffen the electrode and at the same time decrease the weight."

*Secondary Battery.* Isidor Kitsee, Philadelphia, Pa. Patent No. 718,037. January 20, 1903. Application filed April 28, 1900.

The object of the invention is to produce a battery of the Faure type. It is built up of individual blocks, about 4 inches long, 3/4 inch thick and 1 inch high. In order to form an electrode, the blocks can be laid upon each other with or without the interposition of a conductor. The blocks consist of a skeleton, with two face plates and three connecting lugs, consisting preferably of lead or a lead alloy. This is cast or molded, and the active material, preferably oxide of lead, is pressed into the spaces.

*Electric Accumulator Plate.* Auguste Bainville, Nanterre, France. Patent No. 719,418, February 3, 1903. Application filed July 14, 1902.

The improvement applies to storage batteries composed of rods, and consists in placing between the individual rods of a plate a corrugated sheet of insulating material. The sheet is perforated, so as to give the electrolyte access to the rods, and passes around adjacent rods of the same electrode in such a manner as to alternately cover half the circumference of each rod, covering the face of one rod and the back of the next. Thus the imperfection in the distribution of current between the plates, which may occur through the cylindrical shape of the rods, is for the greater part done away with.

*Storage-Battery Tank.* Bruce Ford, Philadelphia, Pa. Patent No. 719,778, February 3, 1903. Application filed December 11, 1902.

The objects of the invention are to provide a tank, the lining of whose compartments can be flanged all around the top of the latter, in order to prevent accumulations of acid, dust, etc., between the compartment, which would tend to produce short circuits, to provide for the draining of the acid which may find its way between the compartments and to provide a reliable, durable and efficient storage battery tank. Each compartment is lined with an acid-resisting material, such as sheet lead or antimonial lead.

*Storage Battery.* Bruce Ford, Philadelphia, Pa. Patent No. 719,937. February 3, 1903. Application filed December 10, 1902.

The specification describes means for holding down wooden separators, such as are used between the plates or elements of a storage battery, and are buoyant in the electrolyte. The holder is generally oblong and provided with curved parts, so that it can be sprung into place above the separators and, by pressing upon the walls of the jar, remains in position.

*Secondary Battery.* F. Buchanan, Dayton, Ohio. Patent No. 720,321. February 10, 1903. Application filed March 1, 1901.

The battery is constructed of an outer circular containing cell, which constitutes the negative electrode, an adjacent circular cell constituting both positive and negative electrodes and an inner electrode constituting a positive pole electrode. The intervening cell or electrode divides the electrolyte from the inner and outer electrodes. These electrodes are formed of lead, unmixed with alloys. The outer containing cell has a series of circular or spirally-arranged ribs on its inner surface; the second cell has such ribs on both surfaces, and the inner electrode on its outer surface. A number of recesses are thus formed, which are adapted to contain the active material.

*Process of Preparing Storage-Battery Plates.* R. N. Chamberlain, New York, N. Y. Patent No. 720,326. February 10, 1903. Application filed March 3, 1899.

The inventor proposes a pickling bath for storage-battery plates preparatory to forming them, which consists of a solution of 4 to 6 per cent. of nitric acid in water. The unaided action of such a solution on the lead plate would be extremely slow, but by connecting the bath in an electric circuit, so as to constitute the plate an anode, a rapid attack of the plate takes place. The lead dissolved from the plate, when it is allowed to remain in the solution, rapidly deteriorates the latter, but by the electrolytic action it is removed as fast as it is formed and deposited on a cathode, thus maintaining the efficiency of the pickling solution.

## GALVANIC CELLS.

*Galvanic Battery.* H. Halsey, New York, N. Y. Patent No. 719,059, February 3, 1903. Application filed September 21, 1901.

The specification describes in detail a galvanic cell, the carbon element of which is in the form of a disk, and movable, while the zinc element is stationary. The idea is the same as that set forth by the inventor in patents Nos. 717,394 and 717,395, ELECTROCHEMICAL INDUSTRY, February, 1903, page 218. Complicated contact devices and rubber gearings are employed. Claim 1 reads: "In a battery the combination of a case containing a plurality of independent cells, each of which contains an excitant, a horizontally-mounted revolvable shaft and an independent rotatable element, comprising a disk vertically mounted upon said shaft and immersed in said excitant, an independent driving shaft mounted upon said case and crossing the upper ends of all said cells, independent gearing between said driving shaft and each of the revolvable elements in said cells, whereby movement of the shaft causes movement of all said elements, and means for gradually feeding a chemical depolarizing agent to the excitant solution."

*Electric Battery.* H. Halsey, New York, N. Y. Patent No. 719,060. February 3, 1903. Application filed April 18, 1902.

This patent covers another construction for moving one of the electrodes of a galvanic cell or the electrolyte, or both, whereby the electrodes are brushed by the electrolyte and kept clean. An electric motor, fed by current from the battery itself, is used again to furnish the power.

*Electric Battery.* H. Halsey, New York, N. Y. Patent No. 719,061. February 3, 1903. Application filed April 18, 1902.

The main objects of the present invention are to provide a simple means for maintaining constant motion between the electrolyte and the elements of the battery, to increase the working surface of the elements, and thus increase the capacity of the battery without increasing the rise of the battery, and, further, to avoid the necessity of swiveled connections between the conductors and the elements of the battery. A steam engine is used as motive power in this case.

*Voltaic Cell.* M. E. Conrad, Atlantic, Iowa. Patent No. 719,752. February 3, 1903. Application filed December 18, 1900.

The inventor says: "In the cell of my invention polarization is prevented by the conversion of the hydrogen of polarization into sulphuretted hydrogen gas. This action is most conveniently effected by using as a negative plate a sulphide of one of the metals. The nascent hydrogen, coming into contact with the sulphide, readily unites with the sulphur to form $N_2S$, which is immediately driven off. Of the various sul

phides with which I have experimented (sulphides of iron, copper, lead and others), the sulphide of iron is superior in working entirely clean, giving a strong current and being cheap. In making my non polarizing plate of a sulphide of iron, I may use natural iron pyrites or a sulphide artificially made from a carbonate of oxide of iron." The best results are obtained by the use of zinc and sulphide of iron elements and dilute $H_2SO_4$, KOH or NaOH as the electrolyte.

*Electric Battery.* E. R. Gill, New York, N. Y. Patent No. 720,577, February 17, 1903. Application filed June 26, 1900.

The invention relates to an arrangement for making tests on electric circuits. A number of dry cells are arranged in a retaining block, and provision is made for quickly making connections between any two cells in the total series, thus obtaining the desired potential.

*Electric Battery.* M. M. Kohn, Chicago, Ill. Patent No. 720,502, February 17, 1903. Application filed July 31, 1895.

The battery belongs to the class of dry batteries having a retaining vessel made of brass, into which fits a lining of the positive electrode, zinc. The preferred electrolyte depends on the negative element employed. If it consists of copper oxide, caustic soda is used as electrolyte; in the case of carbon or peroxide of manganese, sal ammoniac is used, and in the cases of a silver compound, chloride of zinc constitutes the electrolyte. An improved construction of a carbon electrode, consisting of a series of carbon disks and depolarizer disks arranged alternately, is shown.

*Electric Battery.* V. G. Apple, Dayton, Ohio. Patent No. 720,653, February 17, 1903. Application filed June 3, 1901.

The patent describes a storage-battery cell, consisting of a containing cell made of lead or a lead alloy, cast, forced or otherwise formed together with a series of plates, running parallel to its side walls. The bars of which such plate is composed consist of a series of parallel strips, between which the active material is filled in. Another series of plates, joined to a connecting bar, is arranged between the first series of plates, forming the other electrode of the battery.

### Miscellaneous.

*Machine for Oxidizing Matrices for Electrotyping.* C. M. Oliver, Baltimore, Md. Patent No. 719,953, February 3, 1903. Application filed August 26, 1902.

The object of the machine is to apply iron filings or other fine metallic particles to the face of molds or matrices and to spread and distribute them more promptly and uniformly than heretofore. The mold which is to be electrotyped, having been prepared for oxidation, is placed in a trough which can be rocked by suitable mechanism. Iron filings or other particles are shaken down on the mold from a sieve. The trough is open, and contains a liquid, and may also contain a bag of metallic salts of a character calculated to attack the iron filings, *i. e.*, sulphate of copper. When the trough is rocked, any liquid in it is swashed back and forth over the mold, carrying with it the fine particles of metal shaken down on the mold. The waves of liquid wash the particles of metals back and forth over the mold, and the chemical in the liquid acts with great efficiency on the particles.

*Water Purifier.* Joseph Johnson, Minneapolis, Minn. Patent No. 718,935, January 20, 1903. Application filed September 23, 1902.

The apparatus is illustrated in Fig. 4 in longitudinal section, and consists of a metal pipe 2, provided at its receiving end with a nipple 3, to which the water-supply tube is attached. The pipe is divided for a portion of its length, in order to securely fasten into it, by means of lugs 8, a cylindrical insulation of glass or porcelain. This insulator fits snugly within the pipe, and is provided on its inner surface with 2 dovetailed ribs. These ribs hold the electrodes 9 and 10 in place, and, in order to provide still more electrode surface, grooves are arranged in the ribs, and flat plates 15, 16 are respectively connected by wires 17, 18 to the electrodes. The plates, as well as the electrodes, are made preferably of copper. Air tubes 18 are also provided, in order to aerate the water. As soon as the water enters that part of the pipe between the electrodes, the circuit will be closed and the stream subjected to a current of sufficiently high potential to destroy all animal or vegetable life.

*Water Purifier.* E. Kaiser, New York, N. Y. Patent No. 719,471, February 3, 1903. Application filed May 8, 1902.

The apparatus described is intended to be connected with the three-wire system. The inventor's claims read: "In an apparatus, a casing provided with a bottom portion having an

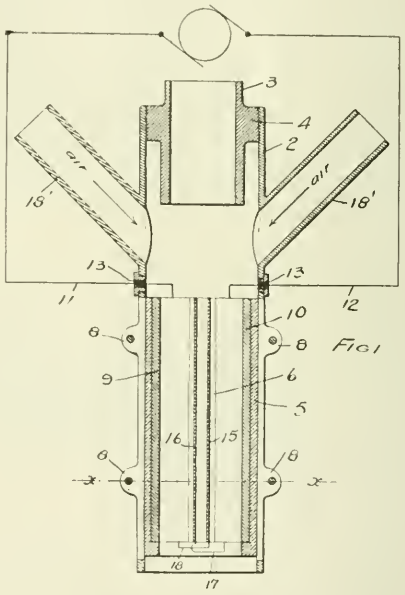


Fig. 4.—WATER-PURIFYING APPARATUS.

insulating cover, an insulating plate secured in said casing midway thereof and forming a bottom compartment, a plurality of spirally-arranged metal plates connected with said insulating plate and removable therewith, said spirally-arranged plates being divided into sets, the inner terminals of which are near the center of said compartment and the alternate plates of each set at their inner terminals, being in electrical connection with a binding post secured to the top of said insulating plate, and the outer ends of the other spiral plates being in connection with the casing, said casing being also provided at one side with a water supply, and at the opposite side with a water-discharge pipe.

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Niagara Power in Ontario.—There is a rumor that all the important municipalities within a radius of 100 miles of Toronto will co-operate in an effort to secure a Niagara Falls power concession at the approaching session of the Ontario Legislature. It is proposed to run trunk cables from Niagara Falls east as far as Toronto and west as far as London, Ont., and supply power to the different places along the routes. It is claimed that power can thus be obtained at a cost at least 50 per cent. lower than that of the present steam-produced electrical power in Toronto, which is $40 to $60 per horse-power year.

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

By Carl Hering.

## INDUSTRIAL ELECTROCHEMISTRY.

*Dressing Ores by Means of Static Electricity.*—The idea of using the repelling force of statically charged particles for separating finely divided ores has at last been applied in practice, and, it seems, with considerable success. The old pith-ball experiments and the dancing paper figures between two charged plates have for years been shown in schools and lectures, but although the forces are by no means very small, relatively, little or no practical use seems to have been made of them until recently. Blake and Morscher have now devised a machine based on this principle, which has been working successfully in Denver for some time. It is described, with illustrations, by Swart in the *Eng. and Min. Jour.*, January 24th. The method consists in bringing a mass of ore particles into contact with a statically-charged metallic surface. Such particles as possess relatively high conductivity are not repelled, while those of low conductivity are repelled when sufficient time has elapsed to allow them to be pulled out of their original path and caught in a separate receptacle, thus effecting a separation from the conducting material. Most of the sulphides and many of the other compounds of the valuable metals possess high conductivity, while the gangue consists largely of non-conducting material, such as quartz, mica, etc. There are exceptions on both sides; the compounds of zinc, for example, are non-conductors, thus allowing a separation to be made between pyrite, galena and chalcopyrite on the one side, and zinc blende on the other, with no preliminary roasting, dryness being the only requisite. Magnetite and pyrrhotite may also be separated from blende. A voltage of 10,000 to 20,000 is now used, the static generator being constructed almost wholly of metal, using no glass whatever, self exciting and able to run continuously in the open air without regard to atmospheric conditions and with no more attention than an ordinary dynamo receives. The separating machines, as at present constructed, have a nominal capacity of from 12 to 15 tons per twenty-four hours, working on blende concentrates at 30 mesh. As in most methods of ore dressing, the capacity is largely governed by the mesh, coarse material passing through rapidly, while the fine goes more slowly. Their machine works well on some material at 6 mesh, and will also handle material at 200 mesh with but slight change of construction or adjustment. As in other methods, sizing improves the products, but close sizing is not essential nor even desirable. On an 8 mesh jig concentrate a sizing at one near 20 mesh will usually give the best results, coarse and fine being handled separately on the same machine, which is built double for the purpose. The standard machine is a double one, 24 feet long, 41 inches wide and 81 inches high, using about 1 horse power, which generates the static charge and is the total power consumed. On the mixed sulphide concentrates of the Missouri-Kansas district, consisting of resin zinc with a greater or less admixture of pyrite and galena, the machine does its best work, as far as tests have gone. But it is not confined in its operations to ores of zinc; all metallic substances, most sulphides and arsenides, and some carbonates and oxides are thrown out of a siliceous or limy gangue, and in many instances the extraction is very high; this is particularly true of the sulphides of copper. The machine as originally constructed, makes no middlings; the finely separated products contain all the material originally charged. It can be arranged in case of coarsely crushed ores, to deliver a middlings product for recrushing when necessary. The advantages of the machine are summed up as follows: Low first cost of the machine and nominal operating expense; it separates materials without regard to their specific gravity; it works well at any mesh between 8 and 200; no roasting of sulphides is necessary; no water is required; no piece of the machine weighs 100 pounds, and any intelligent mill man or mechanic can build a machine and keep it in repair.

*Commercial Cyanide of Potassium.*—In an abstract of a paper read before the Chemical and Metallurgical Society of South Africa, published in the same ojurnal, February 28th, Whitby gives the details of some tests which he made to show how the present system of purchasing cyanide for commercial use in the gold industry left the manufacturers a very wide margin for adding impurities. It is very easy for the manufacturer to comply with existing conditions, and yet supply the consumer with a lot of things he can do without. With regard to the importance of these unnecessary impurities, alkaline carbonates takes precedence over any others as tending to increase the alkalinity of solutions; then come cyanates, which are eventually changed into carbonates, and of least importance is the presence of sulphides. In his opinion it is hard to understand why so much discredit has been attached to alkaline sulphide in the cyanide. One of his samples is a cyanide so heavily charged with sulphides as to give quite a considerable precipitate with alkaline tartrate solution, and yet has been extensively used without complaint as to its effectiveness. Laboratory experiments with fresh solutions might show that sulphides are injurious, but not in working solutions containing zinc, which precipitates them as zinc sulphide. In summarizing, he says that a mixture of sodium and potassium cyanide nicely adjusted to 98 per cent. KCy and NaCy has been used, "leaving room for extensive adulteration." The effectiveness of the mixed cyanides being accepted, it would appear desirable to adopt the use of a sodium cyanide, "dropping the fiction" of calling it potassium cyanide, and demanding an efficiency of at least 50 per cent. cyanogen. Or if potassium cyanide is to be used, some limit should be given to the sodium cyanide, merely to control the amount of inactive bodies.

*A New Method for Producing Pyrochemical Reactions.*—Although the electric furnace can be used to great advantage for many purposes, it cannot do everything as some people seem to suppose. It is not a mysterious something, but a well understood tool and like most tools it has its limitations. The science of the high tension discharge, except perhaps that less is definitely known about its action. Rasch in the *Zeit. f. Elektrochemie*, February 10th, calls attention to some of these limitations. He claims that the following requirements must be fulfilled for pyrochemical reactions in general: The electrodes must allow a high energy density and therefore a high temperature, they must not be oxidized and they must not produce a reducing action on the reaction to be obtained. In his opinion carbon will not answer, and he suggests using for pyrochemical reactions, conductors of the second class which are chemically very resistent and stand a high temperature, for instance, rods or tubes of magnesia, aluminum as do, etc., may be used in a similar way as Nernst uses them in his lamp; such resistances must be pre heated, but he does not say how. These materials may be used simply as resistances, but they may also be used as electrodes for electric discharges, but must be pre heated. He thinks the temperatures which can be

obtained in this way are the highest which can be obtained at all.

*Electrolytic Preparation of Oxygen and Hydrogen.*—An illustrated description of the Schoop system of electrolyzing water is given in the *Centralblatt f. Accum.*, February 15th. The application of the pure oxygen-hydrogen flame for soldering purposes is superior to the simple hydrogen flame, as the temperature is higher. In the Schoop system the electrodes are contained in long tubes, in order to keep the oxygen and the hydrogen separate from each other; these tubes are coated on the outside with an insulating material; the length of the tubes is chosen according to the pressure under which the gases are wanted. The following results were obtained with the Schoop apparatus during one year: One electric horse-power hour gives 97.5 liters of hydrogen and 48.75 oxygen (probably under atmospheric pressure); *i. e.*, for one cubic meter of mixed gas 6.8 horse-power hours are required; with warm acid (sulphuric acid of 1.23 spec. gravity being always used) this value is reduced to 6.2 horse-power hours; if the price of one horse-power hour is 1 cent, the cost of the production of one cubic meter of mixed gases is 4.2 to 4.8 cents. The purity of the oxygen if 99 per cent., that of the hydrogen 97.5 to 98 per cent.

*Duesseldorf Exposition.*—In the continuations of Daniell's long serial on electrochemical and metallurgical exhibits at the Duesseldorf Exposition, he gives a review of the zinc, lead, copper, silver, nickel and cobalt mines in the districts of Germany which were represented at the exposition. Exhibits of an electrotype installation of Langbein and of copper tubes of the Elmore Copper Co., are described, also of storage batteries of various German companies and the Goldschmidt thermite process. Heraeus solders aluminium, and the soldering is said to be so perfect that the soldered pieces may be worked with the hammer and may even be rolled into sheets. This process is used for making various forms of aluminium apparatus which are said to be especially suitable for use in plants in which there is danger of the occurrence of nitric acid vapors. The largest exhibit was an aluminium basin of 1,600-liter contents, soldered together from five different pieces. Exhibits of manganese and manganese alloys (manganin) and platinum are also briefly described. The electrochemical industries of Germany alone are said to consume about 1,000 kg of platinum per year. For electrical and electrochemical purposes an alloy of 90 parts of platinum and 10 parts of iridium generally is used, because this alloy has a greater mechanical resistivity than pure platinum. Platinum sheets for electrodes are made extremely thin, down to 0.03 mm. These parts will be found in the *Zeit. f. Elektrochemie*, January 15th, 29th, February 5th and 12th.

*Industrial Electrochemistry.*—J. B. C. Kershaw continues his long serial on industrial electrochemistry and electrometallurgy in the *Elec. Rev.*, giving brief notes on the progress in Europe and America. The notes refer to the Elmore electrolytic copper process, the question of the calcium carbide patents and the use of electricity for glass manufacture in *Elec. Rev.*, January 24th; nickel production in Canada; new water-power centers in America, and the electric production of iron and steel, in *Elec. Rev.*, January 31st; production and use of aluminium in the United States, electric laboratory furnaces, electric chlorates, in *Elec. Rev.*, February 7th; electrogalvanizing, the works of the Ampère Electrochemical Co., electrochemical instruction in Germany, *Elec. Rev.*, February 14th; metallic sodium as a reducing agent, nitric acid and nitrates from the air, electrolytic antimony, *Elec. Rev.*, February 21st; peat-charcoal, barium and its compounds, purification of salt and brine, *Elec. Rev.*, February 28th; the efficiency of ozonizers and carbon disulphide, *Elec. Rev.*, March 7th.

*Aluminium.*—The *Jour. de l'Elec.*, February 15th, begins an article by Pitival on the present conditions of the metallurgy of aluminium, with special references to the article of J. W. Richards in the January number of *Electrochem. Industry*. Sperry has an illustrated article on the use of aluminium in the rubber industry for making forms, in the *Metal. Ind.* (formerly *Alumin. World*), February.

*Polishing and Plating.*—Hawkins continues his illustrated serial on the polishing and plating of metals in the *Am. Jeweler*, February. He discusses sewed buffs, whole buffs, cotton-flannel wheels, rouge, tripoli, crocus, white-buffing compounds, Vienna lime, sand buffing, and scratch brushes.

*Magneto-Electric Machines for Electrometallurgical Purposes.*—There is an interesting article in the London *Elec. Rev.*, February 20th, giving some historical notes which show that magneto-electric machines, driven by engines, had been introduced into the electrometallurgical industry at a date much earlier than is often thought. From a book published in 1844 it is quoted that Woolrich, of Birmingham, "has succeeded in applying the magneto-electric current to the reduction of metals." He used two models, a smaller and a larger, "the small machine, making 1,000 revolutions per minute, deposits 120 ounces of silver per week, and the large machine, making 650 revolutions per minute, deposits from 300 to 400 ounces of silver per week. The great expense of the production of current from voltaic batteries was clearly understood at that time.

## THEORETICAL AND EXPERIMENTAL.

*A New Synthesis of Hydrocyanic Acid.*—A brief article by Gruszkiewicz describes an electrochemical method of making hydrocyanic acid which may be of practical value. The electric furnace is not suitable for such a synthesis, as its very high temperature has a decomposing effect upon the hydrocyanic acid formed. For such a synthesis a discharge method must be used in a similar way as in Bradley and Lovejoy's method for the fixation of atmospheric nitrogen. The production of hydrocyanic acid from acetylene and nitrogen by this method has been tried by Berthelot; there is the difficulty that acetylene is easily decomposed into carbon and hydrogen; Berthelot found that this complication may be avoided by adding to the mixture of gases a suitable quantity of hydrogen, about ten times as much as of acetylene; in this case he found that no carbon was deposited and that the reactions proceeded according to the equation

$$C_2 H_2 + N_2 = 2 H C N.$$

In 100 cc of a mixture of gases, containing 10 volumes of acetylene, 14.5 nitrogen and 75.5 hydrogen, Berthelot found that after the discharges had passed the mixture for one and a half hours, 8 cc (0.01 gram) of hydrocyanic acid had been formed without any deposition of carbon. The present author repeated these experiments and found that while the deposition of carbon does not take place to any such degree as in pure acetylene, nevertheless it took place, and the two ends of the electrodes were soon short-circuited by a carbon bridge; he further found that if the gas mixture did not contain more than about 5 per cent. of acetylene (and 5 per cent. nitrogen and 90 hydrogen), there was no longer any deposition of the carbon. But he believes that this synthesis is far too expensive and complicated to be of practical value. He then experimented with a gas mixture which is cheap and easily obtainable in practice, containing carbon monoxide, nitrogen and hydrogen (water gas, Dowson gas, generator gas). He found that under proper conditions hydrocyanic acid may be obtained. The reaction would take place according to the equation

$$2 C O + 3 H_2 + N_2 = 2 H C N + 2 H_2 O,$$

but the process might also follow the following equations:

$$2 C O + 6 H_2 = 2 C H_4 + 2 H_2 O$$

$$2 C H_4 + N_2 = 2 H C N + 3 H_2$$

Both assumptions would require the same composition of the gas mixture, namely 33.34 vol. C O, 50.00 vol. H, 16.66 vol. N. But with this mixture he could not get hydrocyanic acid by passing sparks through this mixture; he found, however, that it was obtained the more C O and the less H is contained in

the mixture. The best condition for the formation of hydrocyanic acid is a percentage of 49.70 to 52.44 per cent. of C O in the mixture. In his experiments he produced the electric sparks by means of a large induction coil, the primary winding of which was supplied by six storage-battery cells. To get good results the electrodes must be very close together; if they are too far apart he did not get hydrocyanic acid, whatever the composition of his mixture was. His electrodes consisted of two thin platinum wires at a distance of 3 to 4 mm from each other. As the gas mixture used by him is easily obtainable at a low cost in practice, he thinks it is not impossible that the process has a commercial future. The complete article may be consulted in the *Zeit. f. Elektrochemie*, January 22d.

*Electrolytic Superoxides.*—It has hitherto always been supposed that the lead oxide deposited at the anode of a solution of a lead salt is the binoxide or peroxide of lead, $PbO_2$, and the weight ratio of lead to this oxide has been given as 0.866, this being the ratio of the molecular weights of Pb and $PbO_2$. Hollard, however, has found that 0.866 is too great and that higher oxides are deposited; also that the proportion of these higher oxides is the greater the smaller the concentration of the lead in solution. He has investigated this subject, giving a description of his researches in *Comptes Rendus*, January 26th, an abstract of which is given in the London *Elec.*, February 20th. He used platinum electrodes, the anode being platinized, and added nitrate of copper to the bath, so as to get a compact deposit of lead. The ratio Pb to the oxide was found to vary from 0.740 to 0.861 as the concentration was increased. It is most probable that very high oxides are formed, but the author has not determined their exact nature. Lead is not the only metal which shows this phenomenon, as an alkaline solution of nickel pyrophosphate yields an oxide corresponding to the formula $NiO_4$, and a solution of sulphate of bismuth containing a little nitric acid and copper sulphate, yields an oxide of the formula $Bi_2O_5$. These have been obtained only in dilute solution, as the salts are rather insoluble.

*Electrolytic Preparation of Iodoform from Acetone.*—Abbott, in the *Jour. Phys. Chem.* for February, gives an account of a series of experiments made to find the best conditions for this process. In his experiments the cathode chamber consisted of an ordinary breaker of about 500 cc capacity; in this was placed a porous cup of about 120 cc capacity, containing the anode solution of sodium carbonate, potassium iodide, acetone and water; the cathode was a cylinder of iron-wire gauze, and the cathode liquid a 10 per cent. solution of sodium carbonate, and the apparatus was maintained at a constant temperature by means of a water bath. The most favorable conditions for the preparation of iodoform by this method were found to be the following: A current density of not more than 1.35 ampère per square decimeter, a temperature of 75 deg. C., with an anode solution consisting of six grams of sodium carbonate, 10 grams of potassium iodide, 100 cc water, and 5.5 cc acetone added at the rate of 0.5 cc every 10 minutes during electrolysis; these gradual additions are necessary, as in order to keep the acetone from oxidizing and from forming condensation products, only a small quantity must be present in the anode solution at one time.

*Action of Iodine on Alkalies.*—In the continuation of the investigation Foerster and Gyr on the action of halogens on alkalies, in the *Zeit. f. Elektrochemie*, January 1st, they treat more especially of the action of iodine. They determined the different steps in the processes and give the ionic equations representing the equilibria which characterize the different steps.

*Reduction of Potassium Chlorate.*—Bancroft (Transactions Am. Electrochem. Soc., Vol. I, page 65) and Burrows had found that they could reduce potassium chlorate to chloride Brochet, in a brief article on "a so called electrolytic reduction of potassium chlorate," agrees that in electrolyzing potassium chlorate with a copper anode, potassium chloride is obtained, the quantity of which is greater than should be theoritically expected, if a reaction according to the following equation be assumed:

$$KClO_3 + 3H_2 = KCl + 3H_2O$$

but he believes that the theory is entirely different. The ions K and $ClO_3$ act first, at the anode Cu ($ClO_3$)$_2$ is formed, and at the cathode KOH and hydrogen; these products react with one another so that K $ClO_3$ is formed again together with Cu O, which is reduced by the hydrogen to metallic copper, the latter being deposited on the bottom of the cell. He believes that this deposit is a complicated mixture of CuO, metallic copper and the chloride, for he assumes that besides the above process, which he calls the "normal" reaction, there is an "abnormal" reaction according to the equation Cu ($ClO_3$)$_2$ + 6 Cu = Cu $Cl_2$ + 6 Cu O. The reduction of the potassium chlorate is the result of an intermediate action of the metallic copper upon the chlorate. Brochet's article is contained in the *Zeit. f. Elektrochemie*, February 19th.

*Electric Analysis of Mercury.*—In the *Zeit. f. Elektrochemie*, January 1st, Glaser gives an account of an experimental study on the electric analysis of mercury and the solubility of platinum in potassium cyanide. The main results are as follows: The difference observed in the electro-analysis of mercury from a potassium cyanide solution, are due to an attack of the platinum disk serving as cathode, and to the solubility of platinum in potassium cyanide. This solubility is very small at ordinary temperatures and is greatly increased when the temperature rises. The dissolving of the platinum is accelerated considerably by potassium and sodium amalgams. The solution of platinum in potassium cyanide takes place under the development of hydrogen. In a hydrogen atmosphere, gold and silver are not dissolved by potassium cyanide, even in the presence of potassium amalgam.

*Antimony.*—A summary of the investigations on the electrolytic preparation of antimony from its ores is given by Izart in *L'Ind. Elec.*, January 10th.

*Electrons and Ions.*—Reinganum, in an article on the mechanism of electrochemistry, attempts to formulate a theory of the distribution of the electrons in the molecules entering into electrochemical reactions. He finds it necessary to assume, instead of one pair of electrons, as in Helmholtz's theory, that each molecule, say of H Cl, contains two pairs of electrons, the H atom being provided with both a positive and a negative electron, and the Cl atom likewise with one positive and one negative electron. Electrolytic "dissociation" might then be represented by the giving off of one negative electron from the H atom to the Cl atom, so that the H atom has now one positive electron, while the Cl ion has one positive electron and two negative electrons, and thus is negatively charged. When in electrolysis Cl is developed at the anode, each Cl ion gives off one negative electron and thus becomes neutral, having one positive and one negative electron. At the cathode, when hydrogen is given off, each H ion which is charged with a positive electron, receives one negative electron from the anode and thus becomes neutral, having now one positive and one negative electron. Through the external connection, the negative electrons pass from the anode to the cathode, thus completing the circuit. The author works out this idea for the different compounds and shows why the dissociation constant is a measure of chemical affinity. It is probable that the transfer of the supernumerary electron is accomplished even before actual electrolysis takes place. His article is published in the *Ann. d. Phys.*, No. 2, and is abstracted briefly in the London *Elec.*, February 13th.

*Change of Volume and E. M. F. with Pressure.*—When a Clark or a cadmium cell is put under pressure, its e. m. f. is increased, because if the current is reversed through the cell a greater amount of energy is required to maintain it constant in the case when pressure is applied, than that required when

the cell is not under pressure, it was therefore to be expected that the volume of the cell was increased, or that energy was used up in overcoming pressure. Ramsey investigated this change of volume in such cells, and its relation to the change of electromotive force due to the pressure, and published the results in the *Phys. Rev.* for February. He first gives the theory of this subject and then describes his experiments. The value, calculated by him for the increase of volume for the Clark cell, is 0.11 cb mm per coulomb, and for the cadmium cell 0.072. The values found experimentally for the Clark cell are between 0.062 and 0.232, but their mean, 0.105, is in good agreement with the calculated value. The values found experimentally for the cadmium cell are between 0.039 and 0.054, all of which are smaller than the calculated value. He thinks this was due to a bubble of air in the cell.

*Molecular Induction.* A description of some curious phenomena in electrolysis is given by Gross in the *Ber. d. Deutsch. Phys. Ges.*, No. 1, 1903, an abstract of which is pubilished in the London *Elec.*, February 6th, but unfortunately this abstract, from which the present notice was taken, is not quite clear. A square glass trough is filled with a pure concentrated solution of copper sulphate, and two copper wires, reaching nearly to the bottom, enter the vessel and are connected to a high-resistance galvanometer. "A plate of zinc is suspended in the trough across the line of current and closer to one of the wires." Copper is deposited upon the zinc and a nearly constant current is observed going from the zinc plate to the more distant electrode. On moving the zinc plate towards the latter electrode, the current is reversed. He shows that each of the suppositions that would naturally be used to explain this, namely, thermal, concentration or local currents, do not apply. A high e. m. f. may be obtained by "immersing three zinc plates, insulated on one side, into the trough," and connecting the two outside ones with the galvanometer. The author maintains that there is a force not connected with chemical affinity, and, indeed, often opposed to it, which he calls molecular induction. He presupposes some effect of molecular vibrations.

*Catalytic Action.*—Bredig and Watson give a preliminary account in the *Zeit. f. Elektrochemie*, February 5th, of an experimental investigation of the kinetic reasons underlying the fact that a solution of potassium iodide produces a catalytic action upon hydrogen peroxide, the latter being decomposed into water and oxygen.

*Electrodes Sensible to Light.*—Bose found that a cell with gold electrodes in dilute sulphuric acid, which had been charged with the 110-volt lighting current, had a different e. m. f. in the dark than when illuminated, and that the oxygen electrode was the seat of the sensibility to light. Kochan has more recently made a long series of tests with this type of cell, in which he investigated the influence of light of different colors and the action of Roentgen rays, and has published the results in the *Zeit. f. Elektrochemie*, January 8th, 15th and 22d.

*Electrolytic Galvanometer.*—In an illustrated article in the *Zeit. f. Elektrochemie*, February 5th, Heilbrun describes some experiments for demonstrating in schools or before mixed audiences that when a galvanic cell sends current through an external circuit the current flows through the electrolyte of the cell; also he says this fact is often doubted by laymen. He arranges the galvanic cell in the form of what he calls an electrolytic galvanometer by separating the anodic and cathodic liquids of the cell, placing them in two different vessels, each containing an electrode, and then connecting these two compartments by a coil, consisting of a glass tube wound in many windings and filled with the electrolyte. The magnetic action of the current flowing in this coil upon an external magnet needle can be shown, the arrangement being the same as in an ordinary galvanometer.

*Thermo Cells.*—As thermo cells are so frequently used in laboratories of electrochemists, particularly for analyses, on account of their convenience, the description in the *Zeit. f. Elektrochemie*, January 29th, of a new and more powerful one, by Heil, may be of interest here. He first gives a table of the thermo-electric forces of different materials. The greatest e. m. f. is obtained from constant an (Cu60Ni40 alloy) against an antimony-zinc alloy ($Sb_{100}Zn_{57}$); this he uses for his thermo cell. The antimony-zinc alloy becomes much more resistant to mechanical strains if about 3 per cent. of iron is added. He then describes special mechanical devices for getting the most favorable arrangement for heating. The efficiency of his thermo cell is 2.46 per cent., referring to the energy obtained in per cent. of the consumed energy, or 1.23 per cent. referring to the useful energy obtained in per cent. of the consumed energy. The corresponding figures for the more usual thermo cell (Guelcher) are 0.864 and 0.432. He claims that the efficiency of his thermo cell is superior to that of very small steam-driven dynamo sets.

## PRIMARY AND SECONDARY BATTERIES.

*The Nickel-Iron Accumulator.*—It is generally the case that as soon as someone brings out something new of promising value prior inventors crop up to show that they had done it all long before. So often is this done that it almost seems as though a patent ought to be granted to the one who makes a success of a mere idea, rather than to the prior inventor, who merely makes vague suggestions by the dozen, trusting that some will afterwards be perfected by others, in which case he claims the reward. While it would probably be impracticable to make such a change in the patent law, and as such a change might sometimes do real injustice in the other direction, yet the courts, in deciding patent-litigation cases, have the power to take cognizance of such a state of affairs and deal out justice to whom it belongs.

Whether the claims in the following article are justified or not, we give them for what they are worth, as an opinion could be expressed only after a careful investigation. The original article referred to is in the *Nya Daylight Allehanda*, a Stockholm newspaper, and an abstract is given in the *Zeit. f. Elektrochemie*, February 5th. The article claims that a battery like that of Edison's was first described by the Swedish chemist, W. Jungner. In 1899 Jungner obtained a patent, claiming a battery in which potassium hydroxide is the electrolyte, and the plates consist of powdered metallic oxides, which are insoluble in the electrolyte and give a sufficient e. m. f. Before 1900 Jungner is said to have used Cd, Cu, Fe, Mn, $AgO_2$, $Ni_2O_3$ as materials. In May, 1900, a Swedish firm bought the patents, and a few months afterwards trials were made with automobiles, which are said to have given very satisfactory results. "Without exhausting the accumulators below normal voltage, the carriage, with load, is said to have run nearly 150 kw. The weight of the carriage was 528 kg; that of the battery was 290 kg. At the end of the run the carriage had still a speed of 26.5 km per hour." The nickel-silver peroxide accumulators are, however, too expensive. It is also necessary to separate the plates by asbestos, which had become useless after 120 charges, and had to be exchanged. For this reason Jungner later used nickel oxide as a positive plate and iron as a negative plate, for which combination he obtained a patent on January 21, 1901, while Edison's patent is dated February 5, 1901. The note closes with the remark that "a jury has to decide the priority."

*Plates Made of Slabs of Active Material.*—The conclusion of Leimer's article, the first part of which was abstracted in this synopsis last month, is given in the *Centralblatt f. Accum.*, January 15th. The current for the formation of plates of 140 x 100 x 6 mm is 1.5 amperes for the positive plate; for thinner plates, a smaller current is to be used. Thick plates are best formed with nearly constant voltage, which may be 3 to 3.2 volts at the start and about 2.8 volts at the end, so that the current decreases from 3 amperes to about

¼ ampère. The result is that the core of the mass will have a crystalline, and therefore more solid, structure. The acid for forming (see the abstract last month) should be kept at 10° B. The formation should not be interrupted during the night. The ampere hours required for formation are about 35 to 45 per cent. higher than the capacity of the positive plate. For the manufacture of the negative plates, the following additional notes are given: The best composition is about three parts of minium and one part of litharge. The positive and negative plates should be formed at the same time; the latter require about twice the time of the former. The distance between the plates should be kept constant with very great accuracy, and should be equal to the thickness of the plates. After the formation, the negative plates should be kept in pure water (not in air nor in sulphuric acid). The author mentions that the positive active mass may, under certain circumstances, be a source of danger, as a few drops of glycerine on a freshly-formed positive plate cause a strong explosion after a few minutes.

### GENERAL AND MISCELLANEOUS.

*Optical Pyrometer.*—In the proper running of electric furnaces, the measurement and regulation of the temperature may sometimes be of importance, and, as probably none of the more usual instruments for this purpose are completely satisfactory, the following one, which, from the description, seems quite simple and practicable, may be of interest. It was devised by Holborn and Kurlbaum, and, as the former's name is associated with the Reichsanstalt, the apparatus is probably all that is claimed for it. It is an optical pyrometer, in which the sources to be measured are compared with a standard, which is adjusted so as to appear to merge into the source to be measured. The instrument consists of a telescope, which produces an image of the source under investigation in the plane of vision; and in the same plane is mounted the loop of an incandescent filament, contained in a circular globe, which does not perceptibly influence the optical system. A red glass, tinted with cupric oxide, is inserted in the eye piece, so that a homogeneous radiation is secured. Under ordinary circumstances a simple red surface is seen through the eye pieces, and on it the black filaments. The current is then turned on, and is increased until the filament can no longer be distinguished. The filament appears to dissolve in a fiery gas, and it is impossible to locate it except by the terminals, which remain cooler, and therefore less brilliant. The photometer or pyrometer is calibrated by means of a radiating black body, as described by Lummer and Pringheim. *Ann. d. Phys.*, No. 2; abstracted in Lond *Elec.*, February 20th.

*Acetylene Lighting for Small Cities.*—An illustrated description of the acetylene central stations in Kinkau, Griesskirchen, Poechlarn and Strass, in Austria, is given in the *Zeit. f. Calciumcarbid Feb.*, February 13th and 20th.

*Electrochemical Development.*—A summary of the development of scientific and industrial electrochemistry during the year 1902, containing brief references to articles published and patents issued during this year, is given by Krügger in the *Elektrochem. Zeit.*, January, February.

## CURRENT NOTES.

Congresses for the St. Louis Exposition.—The Board of Directors of the St. Louis Exposition voted, on February 10th, to organize an International Congress of Arts and Science in connection with the exposition, in accordance with the recommendations of the Administrative Board appointed in January to formulate a plan. The sum of $200,000 was set aside for the Department of Congresses. This sum will cover the expenses of the International Congress of Arts and Science and the publication of the proceedings thereof, and all other expenses connected with the promotion of other congresses and conventions. The Administrative Board of the International Congress of Arts and Science now consists of President Butler, of Columbia University; President Harper, of Chicago University; President Pritchett, of the Massachusetts Institute of Technology, Boston; President Jesse, of the University of Missouri; Mr. F. J. V. Skiff, director of the Field Columbian Museum, Chicago; Mr. Herbert Putnam, Librarian of Congress, Washington; Mr. Frederick W. Holls, New York, member of the Hague Tribunal. The appointment of Professor Simon Newcomb, of Washington, the eminent astronomer, as president of the International Congress of Arts and Science was confirmed, as was that of Professor Hugo Muensterberg, of Harvard University, and that of Professor Albion W. Small, of the University of Chicago, as vice-presidents of the congress. The president and vice-presidents were created a scientific committee to make detailed arrangements for the congress, subject to the general control of the Administrative Board and the director of congresses. The plan recommended by the Administrative Board was adopted by the directors of the Exposition, viz.:

There will be one general congress of arts and science, to begin September 19, 1904. The congress will have one definite task, namely, to bring out the unity of knowledge, and thus to bring harmony and inter relation into the scattered scientific work of the day. Leading scholars from the whole world will be invited to discuss every theoretical and practical science in its definite position; to trace the development of each science during the last century, and to state the open problems of to day. An honorarium and a sum for traveling expenses will be allowed to all who submit a paper in response to an invitation and who contribute a definite piece of work to the uniform plan. The plan also provides for the active participation of men of affairs. For example, the group on commerce, or on finance, or on labor, will attract business men. Groups on colonial policy, or arbitration, or municipal government, will attract politicians. The plan further provides for the participation of independent associations, national or international congresses of specialists and scientific or popular meetings.

The provision for the publication of the proceedings of the International Congress of Arts and Science, which is made in the appropriation above mentioned, will form a lasting contribution to the scientific literature of the country, and be a permanent memorial to the work of the St. Louis Exposition.

The action of the Board of Directors inaugurates the first attempt ever made at an international exposition to hold a series of related congresses, all of which should tend towards the development of one central idea. The congresses hitherto held in connection with expositions have been entirely independent, and forced to rely upon the convenience and pleasure of persons interested for their attendance. It is the first time also that a definite sum of money has been set aside to obtain the presence of men distinguished in the various fields of art, literature and science. The American Institute of Electrical Engineers is already taking steps to arrange, if possible, for an electrical congress that shall fit into the general scheme.

The official opening of the National Bureau of Standards, in Washington, will take place next summer, and numerous scientists and engineers from foreign countries are expected to attend the celebration. The date will be chosen so that when it is over, the participants may go directly to the St. Louis Congresses.

St. Louis Exposition.—Prof. J. V. Holmes, chief of the Mines and Metallurgy Department, has returned, after an absence of nearly two weeks. He visited New York City, Philadelphia, South Bethlehem, Pittsburg and Raleigh, the capital of his home State. He delivered an address before the Legislature of North Carolina, and feels confident, he says, that this State will be well represented at the World's Fair. A bill carrying an appropriation of $50,000 is now pending. The interest in the Exposition has increased wonderfully since his visit East last December.

## *Correspondence.*

### POROUS DIAPHRAGMS AND CELLS.

To the Editor of Electrochemical Industry:

Sir:—In 1895, while conducting experiments having for their object the simultaneous electrodeposition of gold and mercury as an amalgam upon copper or iron cathodes from solutions of those metals in solutions containing from 0.01 to 1.00 per cent. of potassium cyanide, I used vulcanized fiber in sheets and in tubular form as diaphragms and porous cells, respectively, for the separation of the anolytes from the catholytes with apparently practical success, so far as preventing the undue mixing of the two liquids. The sheet fibre, however, buckled too much to allow even approximate preservation of such plane surfaces as are desirable for diaphragms. The tubes preserved their shape.

To close the bottom ends of the tubes, I used at first soft vulcanized "corks" or stoppers. Afterwards I used soft vulcanized rubber caps, sprung over the ends so as to compress that part of the tubes, instead of expanding them, as the stoppers did while wet.

I used tubes of various diameters and lengths up to 2 feet, and thicknesses of walls from 1-32 to ⅛ inch. Such porous cells withstand the action of weak acids and alkalies indefinitely.

I never made measurements of the specific resistances of these separators. I communicate to you the above facts, trusting that they may be of practical value to workers in electrolysis. N. S. Keith.

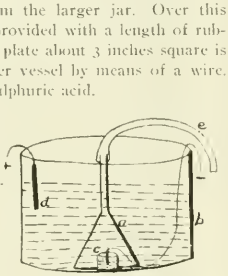
New York, N. Y., February, 1903.

### THE ELECTROCHEMICAL PRODUCTION OF HYDROGEN SULPHIDE.

To the Editor of Electrochemical Industry.

Sir:—I trust it may prove of interest to some of the readers of this paper to give a short account of my experiments in electrochemistry in the line of producing this gas, sulphide of hydrogen, by the action of an electric current upon sulphur in the presence of water. The apparatus is made up as follows: A large glass dish is provided, in the center of which is placed a much smaller vessel, say a 2-oz beaker. This smaller vessel is filled with a mixture of lead filings and powdered sulphur, and is supplied with an electrode of lead connected to an insulated wire, which leads from the larger jar. Over this beaker is placed a glass funnel provided with a length of rubber tubing, and a lead or carbon plate about 3 inches square is hung from the edge of the larger vessel by means of a wire. The vessel is filled with dilute sulphuric acid.

The following rough sketch shows the apparatus:




*a*, the glass funnel; *b*, the large glass jar; *c*, the breaker filled with lead and sulphur; *d*, the lead or carbon plate; *e*, the rubber pipe leading from funnel.

In order to generate the hydrogen sulphide the wire leading from the small beaker is connected to the negative pole of a battery or dynamo, and a current of 3 or 4 ampères sent through the apparatus.

As the water is decomposed the hydrogen unites with the sulphur, with the result that hydrogen sulphide is thrown off, and collects in the inverted funnel, from which it passes through the rubber tube into a receiving tank or pneumatic trough provided for the purpose. The oxygen liberated at the positive pole escapes into the air.

I find this a very convenient method for the generation of hydrogen sulphide, and trust it may prove of value to some of your readers. Frank Balch.

Salem, Mass., February 26, 1903.

### AMERICAN ELECTROCHEMICAL SOCIETY ELECTION.

To the Editor of Electrochemical Industry.

*Sir:*—It was not known until very recently that Mr. Alfred H. Cowles, Cleveland, Ohio, would consent to permitting his name to be used as a candidate for the presidency of the American Electrochemical Society, and therefore it is quite probable that among the list of those indorsed for the offices of the Society, that will be sent out by the Board of Management, his name will not appear.

As Mr. Cowles, with his brother, now deceased, was a pioneer in all commercial electric-furnace work; as the present great development in the commercial manufacture of aluminium had its beginning from the work of the Cowles Electric Smelting and Aluminium Co., at Lockport, and in Europe was an outgrowth of the agencies there set in operation by the Cowles brothers, and as he has probably done more than any other living individual to lay the foundation for the present great growth in the electric-smelting industries, we, the undersigned, think it would be doing both him and the Society a great honor to elect him to the presidency, and therefore we urge you to lend your support to this end.

We call your attention to paragraph 6 of the Constitution, to the effect that voting need not be restricted to the names of those on the lists sent out or indorsed by the Board of Directors.

Wm. O. Mathews, Marcus Ruthenburg, Geo. O. Knapp, Arvid Reuterdahl, Elmer A. Sperry, Wesley S. Block, Loren R. Yorce, John W. Langley, Edward R. Taylor, Isaiah L. Roberts, A. W. Smith, David H. Browne, Willard E. Case, Wm. R. Kenan, Jr., Chas. F. Mabery, Herbert H. Dow, W. L. Goodwin, F. O. Johnson, Perry L. Hobbs, Geo. O. Seward

Cleveland, Ohio, February, 1903.

To the Editor of Electrochemical Industry.

Sir:—A circular letter has recently been sent to the members of the American Electrochemical Society, advocating the election of Mr. Alfred H. Cowles to the presidency of the Society.

The undersigned, all residents of Niagara Falls, and members of the Society, venture to submit for consideration the following reasons in support of their belief that the interests of the Society would not be best subserved by carrying out the action proposed in the circular referred to:

1. The Society is but one year old. It is at present officered by the gentlemen whose brains conceived it, whose energy gave it birth and whose distinguished ability have made it, in its short life, a recognized factor in the scientific world. To us it seems that a failure to re-elect at this time the present executive officers of the Society would injure the bright prospects of the Society, and would show a regrettable lack of appreciation of the disinterested work done by those gentlemen during the past year.

2. In a representative body like this Society, there are included in its roll of members a considerable number of men whose commercial interests are unavoidably competitive, if not actually antagonistic. There are included in the roll members who are engaged in litigation with each other. While this need have no adverse influence on the good of the Society itself, it seems to us that the harmony, and hence the value and influence, of the Society would be best guarded by making it at least an unwritten rule that the principal office should be filled by a man who is not actively engaged in commercial life, and whose election could not be looked upon, even unjustly, as giving his business interests undue advantage over those of his fellow-members through the prestige which very properly would attach to such an honor being conferred by the Society.

3. It seems to us to be detrimental to the larger interests of the Society that at this early stage in its existence politics

should be injected into its affairs by a failure to observe that principle of dignity which is expressed by the sentiment that "the office should seek the man."

E. G. Acheson, C. E. Acker, F. M. Becket, Charles S. Bradley, G. F. Brindley, C. L. Collins, 2d; W. E. Doerflinger, F. A. J. FitzGerald, A. E. Gibbs, C. M. Hall, F. W. Haskell, F. W. Higgins, D. R. Lovejoy, Max Maurax, C. J. Pretzfeld, A. G. Rodgers, J. C. Roberts, T. E. Steere, E. S. Smith, F. J. Tone, C. F. Vaughn, W. M. Whitten.

Niagara Falls, N. Y., March 3, 1903.

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To the Editor of Electrochemical Industry.

Sir:—The question of the nomination of a president of the American Electrochemical Society has been under discussion for a number of months past by some of those members whose only interest is the welfare of the Society. On the one hand the immediate re-election of a president was not considered a good precedent. On the other hand, as the Society is still so young it was thought to be very desirable at the present time to retain in office the chief officers like the president, secretary and treasurer for another year, as their experience during the first year would be of great value to the Society for the second year, after which it was thought the momentum of the machinery of its operation would be sufficient to make it safe to venture to turn it over to others.

After duly considering the pros and cons it was thought best to advocate the re-election of President Richards, and next year to add a clause to the constitution making a president and the vice presidents ineligible for immediate re-election.

It can hardly be questioned that the Society would be benefited most if President Richards would serve another year. With the exception of our indefatigable secretary, there is probably no other member who has taken such a truly unselfish interest in its welfare, and who has devoted so much of his time to its affairs. As a member of the Executive Committee I can vouch for the fact that he has done a very large amount of work, not only in his position as president, but also as the chief working member of various committees. Not only is he one of the recognized leaders of his profession in this country, but he is also a cool, calm diplomat and peacemaker of rare ability, a quality which is very important in any Society which is in danger of being rent into factions. The successful launching of this Society is due largely to what he and our secretary have done for it.

The chief question was, therefore, whether he would be willing to continue to devote so much of his time to the office. This he has consented to do. I, therefore, take pleasure in recommending his re-election. As the results of the recent votes for nominations are not secret, I am not violating a trust if I say that these nominations were overwhelmingly in favor of the re-election of the present officers. The writing of this letter is due to the fact that an effort has been made to elect someone else as president. The directors did not make any official indorsement of nominations this year for evident reasons, as they would either have been forced to nominate themselves or would have to have differed with the large majority of the members.

In the present board the electrochemists engaged in the industries are not as fully represented as would seem proper and desirable, and I would therefore recommend the election as vice-presidents of such members as E. G. Acheson, C. F. Acker, A. H. Cowles (Chas. M. Hall is already a vice-president), and Col. R. M. Thompson, notwithstanding the fact that we thereby lose on the board the valuable retiring vice presidents.

A president should, in my opinion, always be selected from the present or past officers, as he has then had an opportunity to become familiar with the management of the affairs of the Society, and has had an occasion to show whether his allegiance to it is unselfish or otherwise.

Carl Hering.

Philadelphia, March 4, 1903.

## *Book Reviews.*

Monographien über Angewandte Elektrochemie. Third volume: Die Darstellung des Chroms und seiner Verbindungen mit Hilfe des elektrischen Stromes. von Dr. Max Le Blanc, Professor of the Institute of Technology of Karlsruhe. Halle: Wilhelm Knapp. 110 pages. Price, marks 6.

The present volume is the third of the series of monographs on applied electrochemistry. It is divided into three parts, production of metallic chromium by electrolysis of watery solutions and at high temperatures, production of combinations of chromium with metals by electrolysis of water solutions and electrolysis at high temperatures, and production of combinations of chromium with non-metals. The author, who has occupied himself to a considerable extent with the electrolytic production of chromium and its compounds, has made an exhaustive study of the literature of the subject, and has collected a good deal of valuable information in this volume. The following remarks of the author, relative to the question of reproducing patent claims, will give an idea of the scope of the monograph. He says: "One can put the question on this occasion, whether it be expedient to give the contents of such phantastic specifications in a monograph. After considerable reflection, I have affirmed this question and acted accordingly. For, on the one hand, it is not always easy to draw the line between the things which ought to be incorporated and those which ought not, which is entirely an individual question; and, on the other hand, there may often be a grain of gold hidden under a mass of chaff, which might furnish a point of crystallization for later investigations or may prove to be very annoying for a later patent application. . . . The monograph, in contrast to the yearly reviews, etc., aims at a complete review of the subject under consideration, to an extent which should make unnecessary a reference to the original literature, which is sometimes not easily accessible. It wants to report everything, valuable and worthless, that has been done in the field. For these reasons I do not think a selection admissible." The reviewer is disposed to concur with the views of the author as expressed above. In times like ours, when so much is done in the different branches of science, collections like the volume under consideration are apt to be very welcome, especially to people who cannot spend all their time in following the literature. It might seem as though many of the patent claims could have been left out, but the author evidently intended to sin by commission rather than omission. On the whole, the book is a welcome addition to the literature on the subject of chromium and its compounds.

Metallurgical Laboratory Notes. By Henry M. Howe. 8vo, pp. 128. Price, $2.50. Published by the Boston Testing Laboratories, 1902.

The distinguished professor of metallurgy at Columbia University, known to the whole metallurgical world for his work in iron and steel, sets forth in these notes the guides to experimental work which he has evolved for the use of his students.

There are six groups of experiments, the first being a set of ten miscellaneous ones for those students taking a short course in metallurgy and who work in squads; the second set are ten tests in pyrometry and calorimetry, the third set are sixteen on the melting points of silicates and slags; the fourth set are nine of the properties of refractory materials, the fifth set are twenty four on iron and steel, including five tests of microstructure; the sixth set are twenty-two tests concerning other metals than iron.

The idea which has guided the selection of the experiments has been to choose such as make the student familiar with the handling of an instrument of use to the metallurgist, and at the same time illustrate, by the results obtained, some specific metallurgical principle. Professor Howe calls this the analytical system of teaching, and holds that it gives the student

the needed equipment as an investigator of the conditions of manufacture and the quality of product in such a way as can rarely be obtained in an actual industrial establishment. To this end, the experiments cover the use of pyrometers, the fusibility of slags as affected by composition, the properties of steel as affected by different heat treatment, the study of chloridizing roasting, electrolysis of copper, roasting of copper ore, desilverizing of lead by zinc, study of some cooling curves of alloys and their microscopic appearance and many other experiments, all useful and all instructive.

Not only will the student find here the most careful directions for metallurgical investigations, but anyone wishing to do experimental work of this nature for himself will find the book extremely useful. Electrochemists have frequently to conduct experiments involving the use of the same or of similar apparatus and methods, and they will find in the numerous directions and hints or suggestions much which will assist them in their experimental work. The various types of gas and electric furnaces used in the experiments, many devised by or for the author, will interest anyone doing experimental furnace work.

On the whole, we congratulate Professor Howe on the direction which his metallurgical work has taken. The university should not attempt to give the student that experience in actual practice which he can only properly obtain in the works, but it should train the man to observe, think, try and test, and so cultivate his higher faculties in a way which the industrial establishment does not do. Train the student in Professor Howe's way, and his mental alertness will, on leaving college, make up for any slight deficiency in practical experience, which latter he is in the best condition to learn quickly. The university is a place to train a man's brains, not his muscles, and the sight of a student in overalls wrestling with a refractory tap hole to miniature blast furnace in the basement of a laboratory inside the college grounds is a travesty on college education. Such is neither flesh nor fowl, *neither education nor real, practical experience;* it is largely a waste of valuable time and effort.

The teaching of metallurgy in our American universities and colleges will be greatly improved by the adoption of the methods advocated by Professor Howe, and already followed in a few of our technical schools, and we greet his book as an influential factor in that coming improvement.

Einrichtungen von Elektrolytischen Laboratorien, unter besonderer Berücksichtigung der Bedürfnisse für die Hüttenpraxis. By H. Nissenson. 8vo, pp. 51; figs., 32. Price, 3 marks. Wilhelm Knapp, Halle, 1903.

This brochure forms Volume IV of the monographs of applied electrochemistry. The author is director of the laboratory of a large metallurgical firm, and writes with a particular view to the requirements of metallurgical practice.

Ten pages are given up to a very condensed statement of fundamental electrolytic laws and general observations on batteries, conductors, measuring instruments, balances, tables and space requirements. The rest of the work describes in detail the arrangements in the laboratories for instruction at Aachen, Breslau, Clausthal, Darmstadt, Freiberg, Giessen, Konigsberg, Leoben, Munich, Philadelphia (University of Pennsylvania) and at the works-laboratories of Dumon Frères at Lüttich, the desilverization works at Hoboken, near Antwerp, and at the lead works at Stolberg, Rheinland.

The information here given is such that should certainly not be overlooked by anyone who has the problem of arranging for experimental work in electrochemistry. Numerous drawings and photographs show exactly how these successful laboratories are arranged, and the accumulated thought and experience in this line contained in this small and inexpensive book are a welcome addition to electrochemical literature.

## ELECTRICAL MACHINERY FOR OPERATING GOLD DREDGES IN THE KLONDIKE REGION.

Electrical engineers are doing pioneer work for the electrochemists and electrometallurgists. The development is that electricity is first introduced for lighting and power purposes in a metallurgical plant. When electric current is then available, the trial and introduction of electrochemical methods is only a question of time, while also depending, of course, upon the progressiveness of the managers of the plant. For this reason electrochemists should be interested in the rapidly-increasing introduction of electrical machinery in metallurgical districts.

The Western Engineering and Construction Co., San Francisco, Cal., are about to install in the territory south of the Yukon district, a power-transmission plant for the operation of a gold dredge, which will be erected at Atlin, B. C., 2 miles distant from the power plant. This is a new development in the methods of mining in this region, which is a very important placer district; and much gold that would otherwise be lost will be saved by the use of electrically-operated dredges. The work to be done here is similar to that carried on at Oroville, Cal., although the gold is coarser in the Atlin district, being found in nuggets from the size of a pin head to that of an ostrich egg.

The electrical equipment for this plant consists of the following apparatus, recently purchased from the Westinghouse Electric and Mfg. Co.: Two 180-kilowatt belted alternators, which are to be driven by water wheels; two type F variable-speed induction motors, with controllers; two standard type C induction motors for driving the pump, one of 20 horse-power and the other of 50 horse-power, and a 15 horse-power, type C motor for operating screens.

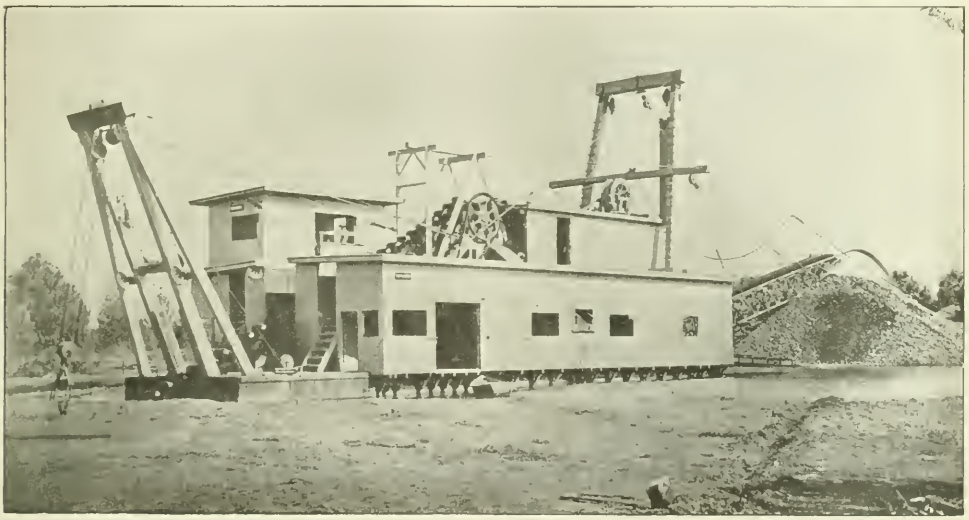
It is interesting to follow the route over which this machinery will pass before reaching its destination at Atlin. From the East Pittsburg works of the Westinghouse Co. the apparatus will be shipped directly across the continent to Vancouver, B. C., from which city it will be reshipped by steamer to Skagway. It will then be conveyed over the Chilkoot Pass to Caribou, by way of the White Horse Railway; carried by teams to Tagish Lake, where it will be reloaded on a small lake steamer and taken to a landing on the other side of the lake; then transported on a narrow-gauge road about 6 miles to another lake; reloaded on another steamer to be taken across this lake, and then freighted to Atlin.

Although all of this work has to be done in a very short season, owing to the severity of the climate, it is expected that the machinery will be in operation in July of this year, and enough gold recovered during the season to pay the entire cost of the installation, which, including the hydraulic machinery, amounts to over $150,000.

A gold dredge costs from $40,000 to $75,000, depending upon its capacity, and consists of the dredging machine proper and the pumping apparatus which supplies the necessary water for washing and sluicing. The dredge machinery comprises a chain of electrically-driven buckets, which pick up the material; a steel hopper, into which the material is emptied; a revolving screen, designed to receive and wash the excavated material; an appliance for carrying off all the coarse tailings and stones that are rejected by the screens, a sluice box, in which the water and fine material containing the gold are disposed of and in which the gold is saved. The stone chute is of a sufficient height and inclination to discharge the material clear of one side of the boat, so that no obstruction can take place on account of the accumulations of tailings. From the under side of the screen all the fine material, including the gold, is discharged with a considerable quantity of water—all of which is carried off and and over the stem of the dredge through a sluice box containing a series of riffles in which the gold is caught, and of a length sufficient to carry the tailings clear of the dredge and to save all the gold. When the gold is of too fine a character to be efficiently collected in the ordi-

nary sluice box, a finer screen and gold-saving tables are employed.

Formerly the dredging apparatus and pumps were operated by steam engines, and this practice is still largely continued. Electric power, however, is preferable, since it admits of the operation of dredges where fuel is difficult to obtain, the lighting of the dredge by electricity and, if necessary, the carrying on of the work at night. An electrically operated dredge is illustrated in the adjoining figure, showing at the left groups of incandescent lamps mounted in reflectors.



ELECTRIC GOLD DREDGE.

## ELECTROGALVANIZING.

Zinc as a protective coating for iron, after a trial of over fifty years, has proved itself to be cheaper and more effective than painting. Iron coated with zinc is called in the trade "galvanized iron" in order to characterize the nature of the protection. Whenever "galvanic" or electrochemical action is set up by the contact of iron and zinc in the presence of moisture it is the zinc which is attacked and not the iron. If the zinc coating is applied by electrolytic deposition, the process is called a cold or electrogalvanizing process to distinguish it from the hot process in which an article is coated with zinc by dropping it in a molten bath of zinc. In the following article we give a description of the electrogalvanizing process of the Cowper-Coles Galvanizing Syndicate, London.

The first care in electroplating is to have a properly prepared surface; all traces of grease and rust must be removed. Machined work, which is usually very greasy, should be immersed for about half an hour before pickling in a hot solution of caustic soda, containing about 2 pounds to the gallon of water; the work should then be placed in a hot pickle containing about 1 per cent. of commercial sulphuric acid.

The removal of mill scale from forgings and plates has always been a matter of considerable difficulty, the scale in many cases being about $\frac{1}{4}$ inch in thickness and strongly adherent. One method is to place the iron in a solution containing one part of hydrochloric or sulphuric acid to 10 parts of water for a period varying from one-half an hour to twenty-four hours. The British Admiralty specify that all steel steam pipes, boiler and collector tubes, and all plates for boilers are to be pickled in a liquid consisting of 10 parts of water and one of hydrochloric acid until the black oxide or scale formed during the manufacture is completely removed. Plates should be placed in the bath on edge and not laid flat. When taken out of this dilute acid all the surfaces are to be well brushed and washed to clean off the loose scale. They should then be placed in a bath, filled and kept supplied with fresh water, and then be placed on end to dry.

During the process of pickling large quantities of magnetic oxide and scales become detached from the plates, which, if allowed to remain in the pickle to be further acted on by the acid, form a serious source of loss. To reduce this loss to a minimum, Mr. Sherard Cowper Coles has devised a magnetic scale collector, which is shown in the adjoining figure.

The figure represents a sectional cut of a lead lined pickling tank, with a scale collector placed in position. The scale collector is connected to the electric supply mains, the current required to work it being about 10 ampères when an e. m. f. of 6 volts is employed. In the case of large baths two or more collectors may be used, or if only one is available it may be moved about to different parts of the bath at suitable intervals. From time to time the scale collector is taken out, and the adherent scale removed either by breaking the circuit or by means of a suitable brush or scraper. The apparatus is attached without any difficulty to any ordinary lead lined pickling vat, and does not require skilled labor to look after it. All the magnetic oxide or scale on the plate is collected almost as soon as it leaves the iron or steel, instead of being allowed to remain in the solution and be acted on by the acid. A large saving of acid is thereby effected.

In this country an electrical-pickling process has been tried, the solution used being sulphate of soda or sulphuric acid. The plates to be cleansed form the negative electrode, and an iron plate the positive electrode; the oxides on the surface are reduced, and any grease that may be present is decomposed. Another method is to use the plates to be cleaned as the positive pole of a galvanic cell, the negative pole being either carbon or wire gauze electroplated with silver and covered with amorphous platinum black, the electrolyte being sulphuric acid at the negative pole and a depolarizer such as nitric or chromic acid being used at the positive pole, so that the evolution of offensive odors is avoided.

Sand blasting is often used instead of pickling, and for many purposes it is found to give better results, especially for cast-

iron work from which it is very difficult to remove the last traces of acid. The process consists of projecting a stream of sand or other abrasive powder at considerable velocity against the surface to be treated. For cleaning iron work compressed air is generally used at a pressure of about 10 pounds per square inch, soft rubber tubes being used for conveying the sand and air to the nozzles, which are of cast steel. The nozzles are quickly worn away, but they are easily renewed at a small cost. The cost of sand blasting per square foot, under the most favorable conditions, including the cost of labor, sand and power, is one-twentieth of a cent, but the actual cost

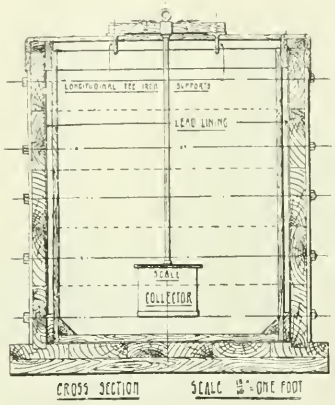



FIG. 1.—MAGNETIC SCALE COLLECTOR.

varies considerably with the nature of work. When using quartz sand of the best quality the loss is about 10 per cent. each time it is passed through the machine; the loss when using chilled-iron sand is very small, the waste of material replacing more than nine-tenths of the apparent loss.

The adjoining figures 2 and 3 show the most recent type of sand-blast equipment, as installed by the Cowper Coles Galvanizing Syndicate for cleaning castings, plates, etc. A is an air compressor; B, compressed air pipe; C, compressed-air reservoir; D, air valve; E, sand jet; F, sand-blast room; G, perforated grating; H, sand hopper; I, sand-section pipe; J, air-

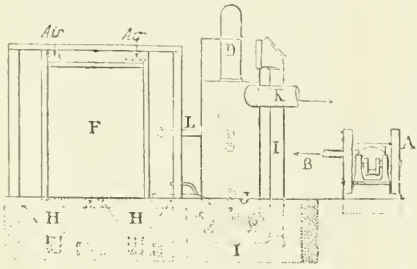



FIG. 2.—SAND-BLAST EQUIPMENT.

washing apparatus; K, inlet pipe, and L, levers for working air or sand valves.

The apparatus shown in the figures is a special one, and is combined with a dust and sand separator and sand elevator. The elevating process is effected by a current of air set in motion by an ordinary exhaust fan. The air washer J is required, if it is desired, to prevent the dust escaping with the exhaust air. This provides for the automatic return of the sand to the sand-blast apparatus in the following manner: The sand, after use, falls through the cast iron grating into the sheet-iron hoppers underneath, and is drawn by the current of air into the main pipe leading into the apparatus. The air to take the place of that exhausted enters through the roof of the room, this prevents the dust from rising. One separator only is required by this system. The size of the sand-blast plant and room is, of course, determined by the size and quantity of the work to be operated upon.

The surface to be galvanized having thus been freed from grease and otherwise cleaned, the article is ready for the zincing bath.

The process of Mr. Cowper-Coles differs from those mostly used in this country, because in the former insoluble anodes are used. He believes zinc anodes are not suitable because, whether cast, rolled, amalgamated, or in the form of granulated zinc, they fail to keep the solution up to its normal strength. As the solution therefore must be regenerated he discards zinc altogether and uses lead anodes.

The electrolyte used in the Cowper-Coles process is constituted as follows:

| | |
|---|---|
| Zinc sulphate ($ZnSO_4 7H_2O$) | 35 ounces |
| Sulphuric acid (specific gravity 1.84) | 0.1 ounce |
| Water | 1 gallon |

To obtain good, bright deposits of zinc the solution should be kept as free as possible from impurities. When the articles to be zinced are first placed in the bath it is found advantageous to use as high a current density as possible, and after a few minutes to reduce it to about 15 ampères per square foot.

For regenerating the solution the addition of zinc oxide has

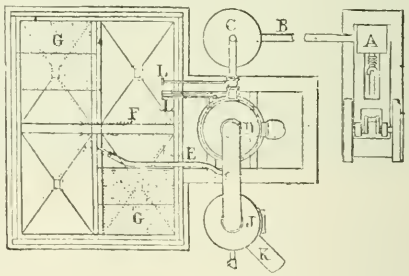



FIG. 3.—SAND-BLAST EQUIPMENT.

been suggested, but the cost is found to be too great. Mr. Cowper Coles has found the additions of zinc dust to the electrolyte to be the only practical method of accomplishing this end. The zinc dust, which contains about 75 per cent. of metallic zinc, and usually a trace of cadmium, is cheaper in the first cost than virgin spelter. The use of it also considerably reduces the waste of zinc, as practically the whole of it is consumed. Zinc dust or tultz is a grayish amorphous substance, and must not be confused with zinc oxide. It is obtained as a sublimal product in the flues of zinc-smelting furnaces. Small quantities of zinc dust are placed from time to time in the regenerating tanks, which are connected to the depositing vats by a system of piping. The electrolyte flows into the bottom of the depositing tanks by gravity, the lighter liquid being drawn off over a sill at the end or in a corner of the vat. It is advantageous to mix the zinc dust with sand or coke and thus form a filter bed, because if the zinc dust is allowed to get into the electrolyte it is found to increase the electrical resistance.

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American Institute of Electrical Engineers.—In our last issue it was stated that the annual meeting of the American Institute of Electrical Engineers would be held in June, at Niagara Falls. We now understand that this has been found to be impracticable, as no hotel is available at that time. There is still a possibility that a joint meeting with the American Electrochemical Society may be arranged for autumn.

## ELECTRICAL EQUIPMENT OF IRON WORKS.

Electrical engineers are doing a rapidly-increasing business in installing electric-power machinery in manufacturing establishments of England, especially in the iron and steel trades. The new machinery and electric plant of Sir B. Samuelson & Co., Ltd., are now in steady and successful operation. Realizing the necessity of adopting the most approved methods of power transmission in these present times of keen competition, this company, an old and prosperous firm, have, during the past summer, installed an electric-transmission plant, including entirely new and modern apparatus, both in the driving appliances and the other machinery, in their works at Newport, in the outskirts of Middlesbrough, England. The contractors for the electrical-power installations are the British Westinghouse Electric and Mfg. Co.

The power is generated in the form of three-phase alternating currents by two steam-driven Westinghouse alternators of the rotating armature type. The steam engines run non condensing, and at a normal speed of 400 R. P. M. Steam is supplied at a pressure of 150 pounds per square inch by four Babcock-Wilcox boilers. The boilers are heated by the waste gases from a battery of coke ovens alongside, being placed between the ovens and a lofty smokestack. The flues are duplicated and fitted with dampers and by-passes, so that any number of the boilers may be heated and regulated as required. Steam-driven pumps supply water from the Middlesbrough and Stockton water-supply system. Injectors are also fitted to each boiler, and a Berryman exhaust steam feed-water heater is included in the steam equipment.

The construction of these alternators insures the best of insulation being obtained, and also renders possible the easy examination and replacing of any single-armature coil without interference with the rest of the winding. The output of each generating set is 175 kilowatts at 440 volts pressure. All of the motors and the electric lighting are supplied direct from the machines. Although rated at 175 kilowatts, the alternators have a considerable overload capacity, and are able to maintain 25 per cent. overload for long periods and 50 per cent. overload for about an hour without undue heating or chance of injury of any kind. Each machine has an exciter, driven by belt from the outer end of the main shaft, and the two exciters being exactly similar and of the Westinghouse multipolar type, four-pole, and each has a capacity of $7\frac{1}{2}$ kilowatts at 125 volts when running at a speed of 775 R. P. M. Each of these machines is capable of providing full exciting current for both alternators running at maximum rated load. The main switchboard consists of six white-marble panels, supported on wrought-iron framework, at a distance of 5 feet from the engine-room wall. There are two machine panels, one exciter panel and three feeder panels, all being fitted with the well-known type of instruments, switches, etc., that are usual in standard Westinghouse practice. The machine main circuits, and also the feeders, of each of the four sets are fitted with fuses. Each of the three feeder panels carries switches and fuse blocks for two sets, one feeder panel thus being available for extensions. The circuits are arranged for the parallel running of the main generators, which, with their exciters and switchboard, are housed in a new building erected for the purpose.

Electric power is used for the rapid handling and breaking of the coal, two motors being installed in the building set up for the accommodation of the coal breaker and elevator gear, these two machines working together and taking complete charge of the coal supply, reducing the labor item to a minimum. The capacity of this portion of the equipment is 50 tons of coal per hour. Another electric motor is installed in a shed at the base of the middle storage bin at the lower end of a conveyor belt, which carries the coal at the rate of about 25 to 30 tons per hour up an angle of 17 degrees. The fine coal is fed into the coke ovens through top doors from small wagons having collapsible bottoms, so as to permit of rapid work in charging. The coke is taken from the ovens by means of an electric ram through a vertical sliding door at each end of the ovens.

An electrically operated overhead crane of 70-foot span travels over the full length of the casting bed, and has a lifting capacity of 4 tons, the power being received from three independent motors, giving a speed of 320 feet per minute. This crane lifts the cold pigs in "comb" pieces of 2 tons or more in weight direct from the casting bed, and carries them to an ingenious breaking machine installed on a raised brick platform. The pigs, as brought forward by the crane, are laid on a long iron table, which has a loose center, to which an undulating motion is given for lifting the long "comb" of the pig forward as it comes under a set of rams. Two rams descend and grip the outer sides of the pig by pressing it down onto the solid table; a middle ram follows, striking the hollow center of the pig and breaking it into three or four pieces. The pigs are broken into lengths of about 2 feet each, and fall down a short open chute into railway cars below. The breaking process and the wagon loading is continuous and automatic. Another ram behind those mentioned serves to break the sow piece as it gradually works its way forward from the gripping ram of that side. All the motions of this machine, both those of the tables and the rams, are produced by a single electric motor, which is coupled to the breaker through spur-reduction gearing.

The nine electric motors for the purposes described are all exactly similar in construction, and in every case, it is stated, have behaved remarkably well under unusually trying conditions. They are three-phase, alternating-current induction motors, of the widely-used Westinghouse type "C" form. This motor is chiefly remarkable for the mechanical simplicity which it combines with a high electrical economy and very low maintenance and operating expenses. With the exception of the three crane motors, which require to have a certain amount of regulation, the motors are each started by means of a double-throw switch, which may be some distance from the motor if desired.

The crane motors are started and regulated by means of Westinghouse commutator type controllers. The set of these, for all three motors, is fixed in the operator's cage, which is suspended from the crane girders at the pig-breaker end, where the man in charge is in the most advantageous position for performing his work of laying pigs quickly and correctly on the breaker table. The controllers are simply designed on an extension of the principle of the starting switch mentioned, having a number of intermediate contacts for supplying various pressures to the motors.

The motor standing at the foot of the fine-coal storage bin works constantly in an atmosphere charged with coal dust, frequently being embedded in an accumulation of fine coal; and when it is cleaned out periodically a large quantity of coal is taken from it. Still it works constantly and well, never receiving any attention beyond a periodical cleaning and an occasional visit from a greaser. The two motors installed together for the operation of the coal breaker and the bucket elevators are subject to similar conditions as the one just mentioned, although to a somewhat less degree.

The motors working the coke rams are subject to high temperatures. The heat radiating from an open oven is very great, even at the distance the motor is away from the oven face. Yet these motors, as well as the crane motors, which are exposed to atmospheric elements and changes, perform the heavy duties required of them in a manner so satisfactory that it is not difficult to understand their individual reputation and the impetus they have given to the installation of electrical equipments throughout the world.

The power station is lighted by a number of incandescent lamps, arranged in pairs across the 440-volt supply mains. There are also 120 incandescent lamps and 12 arc lamps of the

inclosed type distributed to various parts of the works. The lighting system is about to be extended considerably.

The immediate effect of the electric crane and breaker for the handling of metal at the casting beds was the reduction of the staff to the extent of 23 men. The introduction of electrically-driven machinery has not necessitated the employment of new and highly trained workmen. With the exception of the power station, where the steam plant and the control of the generators and circuits call for a certain amount of skilled labor, no work of attendance beyond the ability of the untrained man of ordinary intelligence is required. The men in charge of the electric plant have been drawn from the former staff.

This saving of labor, added to the economies of floor space, transmission, running losses and low lubrication common to all electrical power installations, has made the works of Sir B. Samuelson & Co. a model that might well be copied by his competitors.

## OBITUARY.

A. T. WEIGHTMAN.

In our last issue we reported with regret the death of Mr. A. T. Weightman, formerly the chemist with the Electrical Reduction Co., of Niagara Falls. We herewith reproduce his portrait. Mr. Weightman was taken sick the last day of the Niagara Falls meeting of the American Electrochemical Society. His physician recommended him to resign his position at Niagara Falls and go to his home in England to recuperate. He went to London to undergo an operation, which resulted in his death on February 3d.

## *Personal.*

Mr. Titus Ulke, the well-known electrometallurgist, has accepted a position with the Hyland Paper Co., Johnsonburg, Pa.

Mr. Charles S. Powell, who has been associated with the Westinghouse electric interests since 1893, and who, for the past six years, has been manager of the Cleveland office of the Westinghouse Electric and Mfg. Co., has changed the scene of his activities from the United States to Europe. He has been appointed assistant manager of the British Westinghouse Electric and Mfg. Co., Ltd., and has already entered upon the duties of his new position. His headquarters are in the Westinghouse Building, Norfolk street, Strand, London, W. C.

Prof. R. H. Thurston, of Cornell University, will lecture before the New York Electrical Society next month on steam turbines.

Mr. Robert R. Moffett, Bayonne, N. J., general superintendent of the Orford Copper Co., has been visiting the principal lead and copper smelters of the West.

Mr. John Stevenson, Jr., now general superintendent of the Sharon Steel Co., Sharon, Pa., will soon resign his position, in order to undertake an extensive trip abroad.

Mr. W. B. Mucklow, Hartford, Conn., of Chapman, Mucklow & Bosson, finanical agents for the Majestic Copper Mining and Smelting Co., has been in Utah with a large party of Eastern stockholders of the company.

## TRADE CATALOGUES.

The Combination Rubber and Belting Co., Bloomfield, Essex County, N. Y., sent us their illustrated catalogue on vulcanized rubber goods adapted for mechanical purposes. Rubber tubing, to be used in connection with electric furnaces, is one of the specialties of this firm.

The Dayton Mfg. Co., Dayton, Ohio, have issued a new illustrated catalogue on the Silvey storage battery.

The Croftan Storage Battery Co., Toronto, Canada, sent us a fly leaf on their electrical automobile batteries.

The C. W. Hunt Co., West New Brighton, sent us their catalogue 0225 and pamphlet 0228 on electric hoists.

We received from the Sawyer-Man Electric Co., New York City, several fly leaves on the Sawyer-Man series railway lamp, high-voltage lamp, and reflector lamp.

The Boston Pottery Co. sent us their illustrated catalogue and price list No. 2, 1903, for all kinds of stoneware specialties, fine glazed ware, Rockingham and yellow ware and Bristol ware.

The E. T. Gleason Mfg. Co., New York City, have sent us their nicely-printed and profusely-illustrated catalogue on electric-light supplies.

## INDUSTRIAL NOTES.

The Bullock Electric Co., Cincinnati, Ohio, have secured a motor contract from the Manaduta Mining Co., Japan.

Power Plant Development.—Mr. J. H. Robeling has completed the plans for the development of a water-power electrical plant at old Limekiln Falls in the town of Stockbridge, N. Y. The plans provide for two plants, one above the other, thus using the water twice, and the combined plants will furnish 2,000 horse-power. It is proposed to use the upper power house for supply for Syracuse, and the one on the flats for the use of Oneida and Canastota. Mr. Dewitt Hadcock, of Oneida, owns the water rights.

We are informed from Concord, N. H., that the Connecticut River Power Co. have been incorporated by Brattleboro men, with an authorized capital of $200,000, which may be increased to any sum not exceeding $1,000,000. The Legislature of New Hampshire will be asked for a similar charter. The company will push the project for a dam across the Connecticut River a short distance below the railroad yard in Brattleboro. It is expected to develop here one of the greatest water-powers in New England.

Mexico.—Lauro Barra, of Mexico City, has been granted a concession by the Mexican authorities for the purpose of constructing a hydro-electric plant on the Del Valle River, in the State of Mexico, at a point called Salitrillo, about 45 miles from the city of Toluca. The franchise permits of the use of 8,000 liters of water per second.——The Dos Estrellas Mining Co. are after a concession from the Mexican authorities to permit of the utilization of 25,000 liters of water per second from the River La Ciencga. It is proposed to operate the company's reduction works by water-power and to furnish the mining town of Tlalpujahua, located in the State of Michoacan, with power for electric lighting use.——A 10,000 horse-power plant is to be constructed for the purpose of furnishing energy to operate several of the principal mines located in the El Oro district, Mexico. Jose Luis Reguena, one of the prominent mine owners in that section, has secured the requisite concession. The plant, which will be capable of developing 10,000 horse-power, will be built on the Lerma River. The current will be conveyed for a distance of about 80 miles.

Power-Transmission Plant for India.—The Federal Electric Co., 141 Broadway, New York, have taken a contract for the complete electrical equipment of a transmission plant to be constructed in India for the purpose of generating energy to be conveyed a distance of about 20 miles for both light and power

use. There will be two 150 kw, three-phase generators. The contract for the steam equipment has been awarded to a British concern on the plea of better prices and deliveries being obtained there at present.

THE A. LESCHEN & SONS ROPE CO., makers of wire rope and aerial tramways, have opened new offices at 920-922 North First street, St. Louis, Mo. They will be glad to have mining men passing through St. Louis make the office their headquarters while in the city.

THE RANSOM MFG. CO., Oshkosh, Wis., have obtained some fair-sized orders for grinding and polishing machinery for South America and Mexico.

THE GREAT NORTHERN PORTLAND CEMENT CO., Detroit, Mich., will equip their new plant throughout with electrical apparatus, and have recently purchased from the Westinghouse Electric and Mfg. Co. 23 direct-current motors, ranging in size from 5 horse-power to 50 horse-power. These motors will be applied to driving cement machinery of all kinds.

THE LLEWELLYN IRON WORKS, Los Angeles, Cal., are to be equipped throughout for driving by electric motors. Induction motors will be direct-coupled or belted to lathes, planers and other machinery, and line shafting will be entirely done away with. The Pacific Light and Power Co. have recently purchased from the Westinghouse Electric and Mfg. Co. for this plant 20 induction motors, ranging in size from 2 horse-power to 75 horse-power, which are now being installed.

THE CLEVELAND HARDWARE CO. are installing a complete electrical equipment for the operation of their plant, and have recently purchased from the Westinghouse Electric and Mfg. Co. one 75 kilowatt and one 100 kilowatt, two-phase alternators, together with exciters, switchboard, ten 20 horse-power motors and two 10 horse-power motors. The plant is already in operation, and is doing very satisfactory work. Geo. S. Rider & Co. are the engineers.

THE TERRENATES CONSOLIDATED MINING CO., Parral, Mex., have placed a contract with the Denver Engineering Works, Denver, Colo., for the installation of a complete plant for the transmission of 600 horse-power to be used for the operation of hoisting and pumping machines. Steam turbines to be built by the De Laval Steam Turbine Co., New York City, will furnish the current, which is to be conveyed by means of aluminium conductors to the hoists and pumping stations, about 1½ miles. Frank B. Rae, of New York City, consulting engineer of the Terrenates Co., will have charge of the work.

THE BISHOP & BABCOCK CO., Cleveland, Ohio, are equipping their machine shop for electric driving. The group system has been adopted and short lengths of line shafting throughout the shops are driven by Westinghouse induction motors. Seven or eight of the latter, ranging in size from 10 horse-power to 40 horse-power, have been purchased and are now in operation, current being temporarily supplied from the plant of the Cleveland Twist Drill Co., who are also equipped with Westinghouse apparatus. The Bishop & Babcock Co., however, are installing a power plant of their own, and have recently purchased a 175-kilowatt, two-phase, Westinghouse, engine-type alternator, with switchboard complete. Geo. S. Rider & Co. are the engineers for the plant.

GENERAL ELECTRIC-STANLEY.—It is stated that the much-discussed deal between the General Electric and Stanley interests has been closed, but does not include the Electric Storage Battery Co., as had been expected. The Pittsfield works of the Stanley Co. will be carried on as usual, special attention being given to high-voltage polyphan apparatus.

NATIONAL CARBON REPORT.—The annual report of the National Carbon Co. shows that the company's assets February 1, 1903, amounted to $10,324,028.88, of which $9,270,000 was in real estate, plants, machinery, etc.; $448,215.57 in merchandise, manufactured and unmanufactured, and $364,601.51 in bills and accounts receivable. The liabilities include: Preferred stock, $4,500,000; common stock, $5,500,000; accounts payable, $89,278.01, and profit and loss, $156,000.87. The net earnings of the company for the fiscal year ended January 21st were $594,371.76.

GOULD STORAGE BATTERY CONTRACTS.—Among the recent contracts closed by the Gould Storage Battery Co. are the following: Philadelphia and Lehigh Valley Traction Co.; battery to be located near Quakertown, Pa.; 196 cells in glass jars and switchboard; discharge capacity, 200 ampères. Warren Electric Street Railway Co., Warren, Pa.; 240 cells in glass jars, switchboard and Gould regulating booster; discharge capacity, 160 ampères. Dayton and Muncie Traction Co., 4 plants, located at Winchester, Ind.; Selma, Ind.; Union City, Ohio; Greenville, Ohio; each battery consisting of 305 cells in lead-lined tanks; plate capacity, 320 ampères; tank capacity, 400 ampères; switchboard and 44-kilowatt regulating Gould booster. Odell Illuminating Co.; battery located at Odell, Ill., consisting of 124 cells in jars; capacity, 240 ampere-hours at 240 volts, for three-wire lighting system. Manhattan Heat, Light and Power Co.; battery located at St. Paul, Minn., consisting of 56 cells in lead-lined tanks; capacity, 2,080 ampère hours; switchboard and automatic Gould booster for block lighting and regulation.

THE new plant of the Osceola Silica and Fire Brick Co. at Osceola Mills, Clearfield, County, Pa., will be ready early in April. The plant will have an output of 25,000,000 fire brick annually, while a large output of silica brick has also been provided for. The company were recently incorporated with $100,000 capital. Charles Rowland is president; H. W. Todd, treasurer, and R. L. Coffey, secretary and general manager.

## THE WESTON ELECTRICAL INSTRUMENT COMPANY ESTABLISH A NEW YORK OFFICE.

For the greater convenience of their numerous customers and to better care for the continued increase of business in New York and vicinity, the Weston Electrical Instrument Co., Waverly Park, Newark, N. J., have opened a New York office, at 74 Cortlandt street. This office will be under the management of Mr. Caxton Brown, who has a theoretical as well as a practical knowledge of the different instruments manufactured by the Weston Co. and their particular adaptabilities. This will enable any purchaser or any person visiting or doing business in New York, who may wish to make inquiries relative to electrical measuring instruments, to come in direct contact with a man who is properly qualified to answer such inquiries.

There will be a show room in connection with the New York office, in which will be exhibited the different types of Weston instruments and their special advantages; also the individual parts which make up the instruments. Besides being a great convenience to customers, the New York office will eliminate much correspondence in the nature of inquiries, thus reducing time of delivery of orders.

A general impression has prevailed that the Weston Electrical Instrument Co. only made voltmeters and ammeters, which is not the case. Having what are credited with being the largest and best-equipped works in the world for the production of electrical measuring instruments of all kinds, the company are particularly fitted to turn out work of any special character in which the highest excellence of mechanical and electrical work and design are the important features.

They have, in fact, been turning out a large amount of special laboratory apparatus for several years past, and are now prepared to make standard cells, standard resistances, galvanometers and the highest grade of special bridge work, speed indicators, etc.

The Weston Electrical Instrument Co. extend a cordial invitation to all interested in the subject of electrical measurements to make use of their New York office, either for the purpose of inquiry on the technical points involved or for the prospective purchasing of instruments.

## DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

*Compiled by Byrnes & Townsend, Patent Lawyers*
*National Union Building, Washington, D. C.*

*This digest of electrochemical United States patents prior to July, 1902, will be one by classes, setting out for comparison in each class those devices which have the same object, or those methods which seek the same results. In each class the patents will be arranged chronologically. The digest will be complete in the sense of covering every point which is touched upon in the original specification.*

504,311. July 21, 1890; James Mercer, Rumford Falls, Me.

Anode compartment, a pottery cup with vertical slots through lower half, surrounded by a winding of asbestos paper. Wire gauze cathode clamped around asbestos. Cup has a side opening and reservoir for feeding salt and indicating level of electrolyte within; also a cover sealed by water or oil.

571,591. November 17, 1896; James Hargreaves, Farnworth-in-Widnes, and Thomas Bird, Cressington, England.

Electrolyses sodium nitrate, potassium iodide, etc. Cell built up of a series of frames, between which are clamped diaphragms of asbestos or glass cloth, impregnated with barium or strontium sulphate. Frames of anode compartments, pottery or glass. Frames of cathode compartments, metal, serving as terminals for cathodes. Electrolyte in second, fourth, sixth, etc., compartments only. First, fifth, ninth, etc., compartments contain exposed anodes of wire gauze or perforated plates of carbon with serrated faces, clamped against diaphragms. Third, seventh, eleventh, etc., compartments contain exposed cathodes of wire gauze or perforated metal. Introduces steam into anode compartments to volatilize and remove iodine, nitric oxide or other anion. May also run water down between anodes and diaphragm. Washes off cathode products by a water spray.

579,250. March 23, 1897; Elbridge Baker, Winchester, Mass.

Diaphragm cell, comprising a barrel or cask lined with a mixture of sand and cement. Transverse, vertical central diaphragm, also of sand and cement. Mixture contains only sufficient cement to bind the particles of sand. Feeds salt to anode compartment; brine to cathode compartment. Anode, pieces of retort carbon strung on a copper rod and joined by cement, lead being cast between the rod and the carbon pieces.

583,330. May 25, 1897; Ernest Arthur Le Sueur, Ottawa, Can.

Supplies hydrochloric acid to the anode compartment to neutralize the caustic which diffuses through the diaphragm.

589,230. July 13, 1897; L. P. Hulin, Modane, France.

One or both electrodes, a porous plate or tube, through which the electrolytic products escape, to prevent recombination. Such "filter electrode" may be of porous carbon, spongy or porous metal, a grid filled with "powders suitably agglomerated or of porous or spongy substances of the kind used in electrodes for secondary batteries," or thin, superposed metal strips or rings. Behind each "filter electrode" is a receiving compartment for the electrolytic products, which may be entirely drained or allowed to partly or entirely fill and overflow. When the level of liquid in the electrolyzing compartment is higher than in the receiving compartment, cover upper portion of active face of electrode with a rubber sheet, which extends just below the level in the receiving compartment. Electrodes may be vertical or horizontal, and may be set into and subdivide a rectangular vessel or be clamped between separate frames. Constant feed to electrolyzing compartment assists in pressing electrolytic products through electrode. May also maintain a vacuum in receiving compartment. May or may not use a diaphragm between electrodes. Examples of electrolytic products: caustic potash escaping through porous cathode and sulphuric acid escaping through porous anode.

596,157. December 28, 1897; J. Hargreaves, Widnes, England.

Cell consists of three compartments, parallel diaphragms of asbestos paper, impregnated with hydrated calcium or magnesium silicate, being clamped between an intermediate non-conducting frame and outer receiving chambers of cast iron. Anodes, a row of vertical carbon rods between the diaphragms. Cathodes, exposed sheets of copper-wire gauze clamped against outer faces of diaphragms. Sodium oxidized and washed off cathodes by steam injected into the outer compartments, which are empty. Carbon dioxide—*e. g.*, the exhaust of a gas engine or furnace—may be introduced with the steam to carbonate the product. To electrolyze ammonium sulphate, employs submerged cathodes and exposed anodes of platinum-wire gauze or serrated or perforated carbon plates, clamped against outer faces of diaphragms, the sulphuric acid being washed off. May heat cell to assist in driving off the ammonia gas.

600,081. July 5, 1898; W. S. Romme, New Rochelle, N. Y.

Electrolyses, a moistened layer of salt resting upon a perforated cathode, such as a sheet of zinc. Anodes, horizontal carbon rods in the body of salt. Constantly supplies enough water by means of perforated pipes to keep the salt moistened and wash the caustic down through the cathode. Supplies salt to the moistened layer by angular revolving grate bars above. May place a perforated tray containing lime in upper part of cell to absorb chlorine.

612,069. October 11, 1898; G. B. Baldo, Triest, Austria-Hungary.

Electrolyses sea water to produce caustic soda, hydrogen, chlorine, oxides of magnesium and calcium and sulphuric and hydrochloric acids. Employs two concentric, porous-cup diaphragms. Outer cup consists of a skeleton frame of earthenware, with superposed layers of linen, asbestos board and wire netting serving as cathode. Inner cup consists of a skeleton frame of earthenware, with superposed layers of linen, asbestos board and linen. Anodes, carbon bars in inner cup. Fills inner cup and space between cups with sea water, the space between outer cup and containing vessel being filled with fresh water. Says that magnesium and calcium oxides are precipitated between the cups. Sulphuric acid liberated at anodes, decomposing sodium chloride and producing hydrochloric acid, which is subsequently distilled off. Caustic solution drawn from containing vessel. May fill inner cup with dilute sulphuric acid, thus obtaining sulphuric acid and chlorine only as anode products.

637,410. November 21, 1899; G. H. Pond, Ashburnham, Mass.

Electrolytic cell supported transversely in the middle of an enclosure or casing, which it subdivides into two compartments. A transverse partition depends from the casing into the cell. A diaphragm of sandstone, gradually thickening toward the bottom, may extend from the partition to the bottom of the cell. Anode and cathode, plates of carbon and iron, pressed against pins projecting from walls of cell by a body of moistened salt, which is packed between them. Brine fed to salt by separate wicks leading from reservoirs to inner face of anode and cathode. Caustic solution and chlorine water run out through side openings at the bottom. Superposed perforated trays, containing lime, are placed in the casing outside the anode compartment of the cell to absorb chlorine.

637,851. November 28, 1899; H. Carmichael, Malden, Mass.

A tilting, pipe-shaped device for delivering brine from a reservoir to the cell of patent 518,710, Fig. 10.

641,820. January 23, 1900; W. Barnes, Lynn, Mass.

Maintains a vacuum over electrolyte. May electrolyze ammonium chloride and separately exhaust ammonia and chlorine. Cell may have a diaphragm, *e. g.*, a board having a rectangular opening closed by a block of superposed asbestos sheets. Float feed regulators, with insulated couplings, deliver electrolyte from reservoirs to cell. May introduce electrolyte through a hollow, cylindrical, perforated, revolving electrode.

*(To be continued.)*

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## THE NEW YORK MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The coming general meeting of the American Electrochemical Society is the first to be held in New York City. After the meetings at Philadelphia, as the birth-place of the Society, and at Niagara Falls, as the greatest center of electrochemical industries in the world, it is, of course, New York's turn. New York City is not only the metropolis of the United States, but also the official seat of all the national engineering societies—with the only exception of the American Electrochemical Society. There can be no doubt that in due course of time this Society will also transfer its seat to New York City, and, in view of this fact, the first meeting held by the Society in New York City is of special significance. It is a question open to discussion whether a large city is the most suitable place for a convention of an engineering society. In the present case, however, the elaborate programme which we present in full on another page of this issue, leaves no doubt that the convention will be a full success and a very enjoyable affair. The programme contains a great number of papers on interesting and important subjects, and as, for the first time in the American Electrochemical Society, some of the papers will be printed in advance, we trust the discussion will bring out valuable information. The presence of Dr. Walter Nernst—famous alike as the theorist of concentration cells and as the inventor of the Nernst lamp—gives an international flavor to the meeting. There is every reason to hope that the New York meeting will turn out a success as great and enjoyable as the meetings at Philadelphia and Niagara Falls, and we hope that it will strengthen among its members the esprit de corps—the sentiment that we are all workers in the same field and enlisted in the same cause.

The New York meeting will be the *second annual* meeting—in other words, the Society now enters the second year of its life. It may be proud of the work which it has accomplished in its first year. We need to refer only to the two volumes of Transactions, which it has published, and to the membership list, which is increasing far beyond the first fondest hopes of the founders. It is significant that a large number of well-meaning scientists and engineers who, a year ago, opposed the foundation of the Society, have now become members. In the first year of its life the Society has proven to everyone that it has a mission to fulfill, and that its members are earnest in their purpose to do their duty.

The New York meeting will be the *third general* meeting of the Society. That means that the first year's work was done in only *two* large meetings. Probably the usefulness of the Society would be enhanced if more meetings would be held, at shorter intervals; of course, a meeting of one evening could be of a local character only, and this brings up the question of

the advisability of local branches of the American Electrochemical Society. New York, Niagara Falls, Philadelphia, Cleveland and Madison, Wis., have enough resident members to warrant the foundation of local branches. In various other national societies this institution of local branches has proven very successful. Of course, these local branches should always be under the control of the national Society, and the two general meetings per year should be held in future as heretofore. We think the matter is of sufficient importance to warrant a discussion by the members at the New York meeting.

## "SILOXICON."

Before the simple experiment of subjecting commingled silica and carbon to intense heat had been tried, it would have been difficult to realize that within a few years a literature equal in extent to many volumes would cluster about the reaction. The far-reaching commercial value of a seemingly simple discovery is a familiar experience, but that a reaction apparently so simple should prove so fruitful a field for research is surprising. The product first obtained was not silicon, as might, perhaps, have been expected, but its carbide. Furthermore, not one carbide, but two, appeared, the one a crystalline body of extreme hardness—carborundum—and the other amorphous and differing sharply from the first in certain of its chemical relations. Next in order it was noted that these carbides were not final, but intermediate products, and that a still higher temperature broke them down, volatilizing the silicon and leaving the carbon in the form of graphite: thus a second and most fruitful field was opened. Under proper conditions, however, it soon appeared that elemental silicon might, indeed, result from the reduction; and so the third page was turned.

From a new patent granted to Mr. E. G. Acheson and discussed in this issue's Analysis of Current Electrochemical United States Patents, it appears that a fourth product, "siloxicon," is to be added to the list—a compound, or, perhaps, a series of compounds, containing all three of the elements in the reacting bodies, possessing most unexpected properties, and resulting from a partial reduction occurring at temperatures which, comparatively speaking, are moderate. It would be hard to find a more striking illustration of the value of the intimate study of apparently simple reactions.

## TANKS.

The tank which contains the electrolyte is one of the most important pieces of apparatus in the whole range of electrochemical engineering. This may appear to be a somewhat exaggerated statement to the theorist, but every electrochemical engineer who is responsible for the satisfactory operation of an electrochemical process on a large scale, knows the difficulties and troubles involved in devising a tank which will stand the test of time. It is at once evident that there cannot be such a thing as a tank of universal applicability, suitable for any and every electrochemical process. A tank is suitable for a special electrochemical process if it is absolutely inert in the various reactions which take place during the process. Pottery ware, metal tanks, especially of iron and lead, wooden, slate, concrete tanks, etc., all of them are satisfactory for special processes, and it is the duty of the electrochemical engineer—and often not the easiest and simplest duty—to find the most satisfactory and, at the same time, cheapest material for his special purpose.

For the electrolysis of chloride solutions slate tanks have been employed to quite a large extent, and their use will certainly be continued and will even increase in future. As long as slate is free from mineral veins, there is almost no action on it by chlorine and alkalies. In an excellent article, published in this issue, Mr. David H. Browne, the chief chemist of the Canadian Copper Co., advocates the use of concrete tanks for the same purpose, and describes in detail how to construct such tanks. In view of the fact that Mr. Browne has had an extended experience of many years with the industrial treatment of chloride solutions, this article will certainly be studied with great interest by our readers. It may sound somewhat paradoxical, but it is nevertheless true, that it is easier to write down and integrate the general differential equations governing the migration of the ions in the electrolysis of chlorides, than to build a cheap tank in which the process may be carried on industrially. We must be thankful to the electrochemical engineer who describes how to do such things.

## ACETYLENE DISSOLVED IN ACETONE.

In this issue we publish a short but very interesting article by Mr. R. S. Hutton, the well-known director of the electrochemical department of Owens' College, Manchester, on a new method of storing acetylene, for which the important claim of absolute safety is made. According to Mr. Hutton, much use is already being made of this method in France, and an English company is preparing to use it extensively. We may add that the same method has also aroused considerable interest in this country for some time. The method is based upon two principles: First, the experimental fact that acetone dissolves a large amount of acetylene and that this mixture has no explosive properties; second, the use of porous material to fill up the whole space of the cylinders in which the gas is stored. This latter device is the new feature of the method, and has been suggested on account of the fact that the solution of acetylene in acetone is accompanied by a considerable increase of the volume, so that when acetylene is drawn from a cylinder in which this solution is stored, the volume of the solution would decrease and the free space thus formed would be occupied by acetylene gas, which would result in the danger of an explosion. To avoid this the use of porous material has been suggested.

This method of storing acetylene is entirely analogous to the storage of compressed oxygen and hydrogen in cylinders, which is now largely in use. The advantages of this method of storing acetylene over the direct generation from carbide are also evident and well pointed out by Mr. Hutton. On the other hand, it cannot be denied that this is a rather roundabout way of using acetylene. The cost of the cylinders and the acetone, the cost of storing and the freight charges will always be considered unnecessary expense, and the ideal at which the electrochemical engineer will continue to aim will always be the design of a simple, cheap and absolutely safe generator of acetylene directly from carbide. It is similar

with the use of compressed oxygen and hydrogen gases in cylinders. They will be used wherever small quantities are needed at a certain place, but if oxygen and hydrogen are needed in considerable quantities at one and the same place, it will be cheaper not to buy the compressed gases, but to install an electrolytic water decomposition plant. With acetylene the conditions are analogous, and for acetylene lighting installations it will always be preferable to use generators for the direct production of acetylene from calcium carbide. However, until the ideal method for this purpose has been found, the method of storing acetylene in acetone will render very valuable service, and we hope with Mr. Hutton that the influence of this method on the carbide industry will be of the most satisfactory nature in opening up many new uses for acetylene gas.

## "OXYGEN-LIFT" STORAGE BATTERIES.

In the Synopsis of last month we printed an abstract of an article in a Swedish contemporary which claims priority for a Swedish chemist, Mr. Jungner, over Mr. Edison in the invention of the celebrated nickel-iron battery. Without wishing at present to discuss this claim, we may record the fact, which does not seem to be generally known, that the general idea of an "oxygen-lift" cell—*i. e.*, of a storage battery in which the electrochemical action consists in the transfer (or "lifting") of oxygen from one plate to the other—is as old as the storage battery itself. When the lead storage battery was invented, involving lead peroxide and lead as the two electrodes in the charged condition, it was thought that during discharge they were changed into lead oxide; the use of sulphuric acid was thought to be necessary only for increasing the conductivity of the electrolyte. We now know that the function of the sulphuric acid is entirely different, and that the lead cell is not an oxygen lift cell. This is one of the many instances of a general, though vague idea of an invention existing long before the real invention was made, or before it was reduced to practice. Of course, such references to prior vague ideas should not have undue weight in deciding who should have the real credit for having accomplished something useful and practical.

## INSULATING VARNISH FOR ELECTRIC MACHINERY.

In this issue we publish a very interesting paper by Mr. C. E. Farrington on defective machine insulation. The subject is of the utmost importance for the electrical engineer who has to construct his dynamos and motors in such a strong and durable manner that they will fulfill their duty even under severe conditions. As Mr. Farrington says, the designer of a motor never can tell which one of his machines will be located in the hottest corner of a rolling mill or may have to stand some day an emergency load in ordinary practice. The design of electric machinery, based upon most exact mathematical theory, has attained in recent years such a degree of perfection that it is safe to say that the weakest points of up-to-date electrical machinery are due to defects of the materials used. The insulating varnish may appear, at first sight, a small detail, but it becomes a matter of considerable importance in view of the undeniable fact that a great many electrical machines are crippled in practice on account of the use of defective insulation.

It is not difficult to understand this condition of things. Electrical designers are always excellent mathematicians and mechanical and electrical engineers, but generally no chemists. The problem of devising a good insulating varnish, however, is a chemical problem. We note with pleasure that among the papers to be read at the New York meeting of the American Electrochemical Society there is one by Dr. M. von Recklinghausen on insulating materials, a field for chemists. On account of its enormous importance for the electric fraternity, this is indeed a field which will be found to be quite lucrative to the chemist who solves the problems involved in this matter.

Speculative minds have asked why one should look for insulating materials, insulating varnishes and paints and the like, as it would be much simpler to cover the copper wire directly with some metallic cover of perfect insulating properties. This is of course only a very vague suggestion and without any value for the practice as long as this coating is not clearly defined. Nevertheless, it is not an absolutely impossible thing, and if a copper compound could be found which has the necessary mechanical, chemical and electrical properties, and which could be easily formed in a thin continuous layer on the surface of copper wire, this would certainly represent the ideal insulation. To quote an analogous, although quite different case, we may refer to the recent brilliant invention of Mr. Acheson, who covers the electric furnace carbon with a sheath of carbide, which is, at the same time, stable at the highest temperature and a good conductor of heat, and thus makes the production of pure metals possible in the electric furnace, while it had been impossible before on account of reactions taking place between the reduced metals and the carbon of the core. But it is useless at present to speculate about possibilities of insulating copper wire with a sheath of insulating copper compound which has, at the same time, all the other required mechanical and chemical properties.

The actual situation is clearly pointed out in Mr. Farrington's article. The copper wire, used in practice, is covered with cotton and an insulating varnish or paint is used for the sole purpose of making constant the initial insulation resistance of the cotton covering. It is therefore important to study the weaknesses of the cotton covering in order to correct them. Mr. Farrington discusses the principal defects of the cotton covering in detail, and, starting from these fundamental facts, he describes in a very interesting manner the long series of tests, extending over a number of years, to find the best constitution of an insulating varnish for general electrical practice. While it is to be regretted that, for commercial reasons, Mr. Farrington does not describe exactly the constitution and manufacture of his insulating compound, the paper is none the less interesting in view of the clear explanation of the reasons why certain materials should *not* be used in an insulating varnish.

## NEW YORK MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

In our last issue we printed the programme of the coming New York meeting of the American Electrochemical Society. As in the meanwhile this programme has been extended or changed in some particulars, we give here again the full programme for the convenience of our readers.

Members and guests will please register at the *Chemists' Club*, 108 West Fifty-fifth street, and receive their badges as soon after their arrival as possible. Badges will be given to all members in good standing and to applicants who have deposited their initiation fee. Special badges will be provided for guests, who must be introduced by a member. All meetings will be held in the large assembly hall of the Chemists' Club, where members in attendance may have their mail addressed, and where all announcements will be made. By the courtesy of the Chemists' Club, its club house, including the library of the American Chemical Society, will be open for the use of members and visitors.

The hotel headquarters of the Society during the meeting will be at *The Wellington*, Seventh avenue and Fifty-fifth street, half a block from the Chemists' Club.

By the courtesy of the *German Liederkranz*, its club house, 111 to 119 East Fifty-eighth street, will also be open to members and guests during the convention. Membership buttons will secure admittance.

On Thursday morning, April 16th, at 9 A. M., a meeting of the Board of Directors will be held, which will be followed, at 10 A. M., by the business meeting of the Society, at which reports of directors and officers will be presented.

Reading and discussion of the following papers: Wilder D. Bancroft, Ph.D., "Constant Voltage and Constant Current Separations;" H. T. Barnes, Ph.D., "Experimental Study of Some Electrode Effects;" J. W. Richards, Ph.D., and W. S. Landis, "The Electrolysis of Water;" Wilder D. Bancroft, Ph.D., "Experiments with Metallic Diaphragms;" C. J. Reed, "Protective Action of Zinc Chloride on Metallic Iron."

At 1 P. M. luncheon will be served at the Chemists' Club, by invitation of the New York members. At 2.30 P. M. reading and discussion of the following papers: Max von Recklinghausen, Ph.D., "Insulating Materials—A Field for Chemists;" H. B. Coho, "A Historical Review of the Storage Battery," with illustrations; Elmer A. Sperry, "The Use of Pyroxyline in Electric Storage Batteries;" W. H. Walker, Ph.D., "The Concentration Changes in the Electrolysis of Brine;" J. W. Walker, Ph.D., "The Influence of Some Impurities in Salt Upon the Yield of Soda by the Amalgam Process;" A. A. Knudson, "The Corrosion of Metals by Electrolysis;" Titus Ulke, "Modern Electrolytic Copper Refining;" N. S. Keith, Ph. D., "A Note on the Composition of Electroplating Solutions;" C. W. Volney, Ph.D., "The Formation of Nitric Acid Under Electric Influences."

At 7 P. M., reception of members and guests in the clubhouse parlors of the German Liederkranz, 111-119 East Fifty-eighth street. At 8 P. M., subscription banquet for members and guests. Ladies are especially invited to participate. The price per cover is $5. A fine musical programme has been arranged.

Friday morning, April 17th, 9.30 A. M., announcement of the results of the election of officers for 1903. Reading and discussion of the following papers: W. D. Bancroft, Ph.D., "Note on Electrical Endosmose;" Louis A. Parsons, Ph.D., "Ions and Electrons;" Carl Hering, "Uniformity in Electrochemical Equivalent;" W. D. Bancroft, Ph.D., "The Electromotive Force of Alloys;" Prof. C. F. Burgess and Carl Hambuechen, Ph.D., "Electrolytic Production of Metallic Compounds;" J. G. Zimmermann, "The Electrodeposition of Metals Upon a Rotating Cathode."

At 1 P. M. luncheon will be served at the Chemists' Club, by invitation of the New York members.

At 2 P. M., excursions to plants and places of interest, as arranged by the Excursion Committee, starting from the Chemists' Club. Three parties are scheduled for this afternoon, each one starting at 2 P. M. The first party visits the Willyoung & Gibson Co. and the works of the Crocker-Wheeler Co., at Ampere, N. J.; the second, the works of the Sawyer-Man Electric Co., the special exhibition at the store of Eimer & Amend and the Cooper Union Institute; the third, the plant of the United States Electrogalvanizing Co. in Brooklyn and the Brooklyn Navy Yard.

At 8.30 P. M. the Society will, by special invitation, be the guests of the American Institute of Electrical Engineers at their extra meeting, held in the assembly hall of the Chemists' Club, at which the programme is as follows: President Scott, "Introduction;" W. J. Hammer, "Radium and Other Radioactive Substances, and Certain Phosphorescent and Fluorescent Substances." "The Properties and Applications of Selerium." "The Treatment of Disease by Ultraviolet Rays."

On Saturday morning, April 18th, 9.30 o'clock, the following papers will be read and discussed: A. B. Marvin, "Electrolytic Conduction Without Electrodes;" P. G. Salom, "A New Type of Electrolytic Cell;" H. E. Patten and W. R. Alott, "Potentials of Zinc in Aqueous Solutions;" Woolsey McA. Johnson, "Notes on Electrolytic Depositions of Nickel;" Alfred H. Cowles, "What is the Capacity of Molecules for Electric Charge in Electrolysis?" B. McNutt, "An Electric Laboratory Furnace;" J. A. Steinmetz, "Exhibit of Aluminium Corrosion;" August Eimer, "Exhibit of New Apparatus."

At 1 P. M. luncheon will be served at the Chemists' Club, by invitation of the New York members.

At 2 P. M. excursions will be undertaken to plants and places of interest, as arranged by the Excursion Committee, starting from the Chemists' Club. Two parties are scheduled for this afternoon, the first visiting the New York Edison Station at Thirty-eighth street and East River, the Seventy-fourth street power house of the Manhattan Railway Co., the Ninety-sixth street power house of the Metropolitan Street Railway Co. and Columbia College; the second party visiting the Rapid Transit Tunnel and Columbia College.

At 8.30 P. M., meeting in the Chemists' Club, Assembly Hall. Presidential address by President J. W. Richards, Ph.D.; Max Von Recklinghausen, Ph.D., demonstration of the Cooper-Hewitt lamp and rectifier.

At 10 P. M. a German-American smoker (Kneipe) will be held at the Chemists' Club, Assembly Hall, buffet, luncheon, refreshments by courtesy of the New York members. A jolly social evening is assured.

Transportation will be on the certificate plan. All members not residing in New York City should secure certificates when purchasing tickets, in order to get return at one-third rate.

The local committee consists of the following members: Dr. C. A. Doremus, chairman; Alvis von Isakovics, secretary; W. S. Cameron, assistant secretary; G. C. Adams, C. Batchelor, C. S. Bradley, Wm. Hand Browne, Jr., Dr. C. F. Chandler, E. A. Colby, Dr. F. B. Crocker, Dr. G. Drobegg, R. A. Fliess, Dr. H. Foersterling, J. C. Hatzel, Dr. N. S. Keith, E. C. Klipstein, A. A. Knudson, Dr. Morris Loeb, W. N. McCoy, C. O. Mailloux, A. Monell, E. H. Mullin, H. N. Potter, Dr. M. von Recklinghausen, E. E. Ries, Dr. S. Sheldon, N. Tesla, W. D. Weaver, E. Weston, C. E. Whitney and Dr. F. G. Wiechmann.

The above elaborate programme shows that the local committee has spared no efforts to insure a full success of the meeting. The attendance promises to be even greater than at the Philadelphia and Niagara Falls meetings.

As we already noticed in our last issue Dr. Walter Nernst, the distinguished professor of electrochemistry at the University of Goettingen and inventor of the Nernst lamp, will be present at the convention.

## CONCRETE TANKS.

By David H. Browne.

In the electrolysis of chloride solutions it is impossible to use lead-lined baths on account of the rapidity with which this metal is attacked both by soda and by chlorine. Wooden vessels are exceedingly awkward—the chlorides appearing to cause shrinkage of the fibers, in which result the hoops or bolts are readily corroded. Slate tanks are satisfactory, but are very expensive and require the utmost care in leveling up and in drawing together. As concrete has been found an efficient substitute for slate, some notes on the manufacture of concrete baths may be of interest.

The first requisite is a good, slow-setting cement. Slowness of set is necessary because in building large tanks it requires ten or twelve hours or even more to carry up the walls to the required height, and as the ramming must be continuous throughout this entire line, it is evident that if the bottom took its initial set before the sides were completed it would be injured by the vibration. The cement, therefore, should take longer to set than the tank to complete. Cheap cement is worse than useless. Saylor's cement has proved a reliable article, but any brand which will stand the "pat" test will be satisfactory.

The "pat" test is made by mixing a handful with water to a stiff paste and working the same on a glass plate into a cake about half an inch high and 3 or 4 inches in diameter. The surface should be troweled smooth and the sides brought down to a thin edge. This is allowed to stand a few hours, then is covered with a wet cloth and set aside in a cool place over night. If it sets slowly and shows no cracks on the surface or at the edges it will answer.

For the best work crushed granite should be used. This has a rough granular fracture or "bite," into which the sand and cement lock better than with any other rock. As the stone used is the weakest part, and as a good concrete, when broken, shows fracture across, and not around the particles of stone, it is important to use the best rock available. Failing granite, a trap rock or blue diorite is a good substitute. The size of the rock depends on the thickness of the walls; a safe rule being that no piece should be over one-quarter the thickness of the wall in which it is used. For ordinary tanks material passing through a screen of $1\frac{1}{2}$ inches, and over a screen of $\frac{1}{2}$ inch is satisfactory. The material smaller than $\frac{1}{2}$ inch should be rejected, as it interferes with the filling of the voids.

The solidity of concrete depends largely on the care with which these voids are filled. To determine the void space, take a pail of crushed rock, calculate the volume and find the weight. Add now water till the pail is full and weigh again. Calculate the volume of the water and simple proportion shows the empty space between the particles of rock. This space must be filled with sand, of which in turn the voids must be filled with cement. The voids of cement are in their turn filled by the water absorbed. Hence for strong concrete the common use of the formula, "4 parts rock, 2 parts sand, 1 part cement." For less careful work a larger proportion of rock is often used.

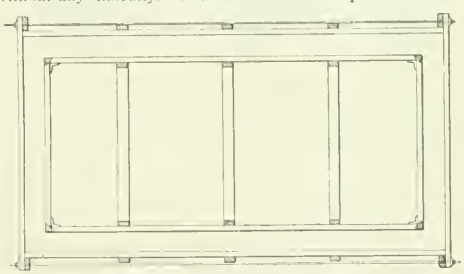
To mix the cement a tight mortar box or floor and a measure holding one cubic foot are needed. The rock should be thoroughly washed, and the sand screened from clay or gravel. One cubic foot of cement to two of sand is mixed on the dry floor to an even composition, and to this four cubic feet of stone are added, and the mass thoroughly shoveled over. Water is now added, so that, while no muddiness is apparent, each particle is moist. The mass is again shoveled over and is now ready for the mold.

This mold may be of any shape whatever. It is set on a solid floor, with a sheet of building paper underneath so that the tank does not bind to the floor. The sketch shows a form for a commercial-plating bath. The outer frame is trued at right angles and braced by struts to the floor to prevent bulging of the sides under the rammer. The concrete is now shoveled in, a few inches at a time, and thoroughly rammed until water shows at the surface. For a tank of the size shown three men are needed ramming and two men mixing and handling concrete. The tools needed are iron rammers, about 2 inches thick and 3 or 4 inches square, with a sleeve for a wooden handle. Such a tool, handled with a short, stiff blow, is better than a lighter tool, with a springy blow, the idea being simply to drive out the air from between the particles and completely fill the voids.

As soon as the bottom is of the desired thickness the inner frame is put in place and braced by cross pieces to prevent inward bulging. The sides are now rammed up, a few inches at a time. It is not desirable to lay the sides in layers, but rather to carry them up without coursing or stratification. One thing is very important, that there be no stoppages. If a meal time intervenes the men should be relieved one at a time, so that no pause occurs till the tank is completed.

The top finish is put on by bringing the concrete to within a quarter of an inch from the top of the mold and carrying this up with equal parts sand and cement troweled to a smooth surface. Any openings or holes in the tank wall are made by inserting a block of wood of the desired size in the side walls. After the tank is set the wood can be drilled or broken out.

Three or four days should elapse before the moldboards are taken down. The inner frame is removed by unscrewing the angle irons shown, when the side boards will drop inward without any difficulty. The outer form falls apart on removal



FRAME WORK FOR A CONCRETE TANK.

of the tee rods. If necessary the inner surface can be finished with a coat of sand and cement, but if planed boards were used for the molds the surface is usually quite smooth.

Concrete will not stand strong acids; caustic or chlorine has no effect upon it. A coating of paraffine or tar would help it to resist acids. It should not be subjected to sudden changes of temperature. If the heat be brought up gradually it will stand fire. It can be handled or lifted like a block of granite if ordinary care be used to prevent the tools from bearing against the sharp edges of the tank.

A tank with 6-inch bottom and 4-inch sides, containing 24 cubic feet of concrete, can be set up and completed by five men in one day. The cost decreases with the number of tanks built at one time and the facilities for handling concrete. Building four tanks of this size per day the cost per tank was as follows:

| | |
|---|---|
| Carpenter and blacksmith labor on molds..... | $1.75 |
| Concrete work labor, 30 hours @ 17½c..... | 5.20 |
| 3.5 cubic feet cement @ 60c..... | 2.10 |
| 7 cubic feet sand..... | .25 |
| 14 cubic feet crushed trap rock..... | 3.00 |
| | $12.30 |

Including finishing, taking down molds, cementing in rubber pipe connections, about $15 will cover the cost of building a tank as above described, the dimensions of which are about 3 feet wide, 6 feet long and 2 feet deep. No construction of lead, slate or wood can be made which will fulfill all the requirements of the case for this sum.

## ACETYLENE DISSOLVED IN ACETONE.

By R. S. Hutton.

Already, in 1896, Claude and Hess, in France, suggested the idea of making use of the solubility of acetylene in certain liquids as a means of storing this valuable gas. It is, however, only recently that any commercial use has been made of such a process, and much credit is due to M. Fouché, the director of the "*Cie française de l'Acétylène Dissous*," and his colleagues for the perfection of the many details necessary to make a technical application at all possible. In view of the fact that already much use is being made of this process in France, and that the Acetylene Illuminating Co., in England, is preparing to employ it extensively in a somewhat modified form, it may be of interest to give a general description of the present condition of this industry and some of its applications.

Amongst a large number of liquids which were found to dissolve acetylene very readily, acetone was chosen on account of its comparatively high boiling point (56° C.), and of its occurrence as a common industrial product. Acetone was found to dissolve 24 times its volume of acetylene at 15° C. at ordinary atmospheric pressure, and as the pressure increases the solubility also very considerably augments.

Careful experiments were carried out by Berthelot & Vielle, amongst others which showed that the solution in acetone possesses none of the dangerous explosive properties which, it will be remembered, have been ascribed to the liquefied gas. It was thus proved that the solution could be safely transported under pressure in steel cylinders similar to those used for liquefied or compressed gases. However, since the volume of the acetone increases very largely by dissolving the acetylene in it, it follows that the cylinders cannot be completely filled with the mixture, but that a space must always be left, which, of course, would be occupied by the acetylene gas at a pressure corresponding to that at which it was held in solution.

Although comparatively little danger was anticipated owing to the small volume of the free gas, and to the fact that pressures above 10 atmospheres were not to be employed, the suggestion of making use of porous materials, to fill up the whole of the space in the cylinders and to absorb the solution was warmly welcomed. The great promise of the method depends largely upon the success of this modification.

Porous bricks and specially-prepared cements have been used, possessing a low density, 0.3 to 0.5, and considerable porosity, up to 80 per cent., and these are found capable of storing the solution of the gas under pressure up to 35 atmospheres without the least fear of explosion; but such high pressures as this are not even approached in the apparatus used for commercial purposes. The cylinders employed by the French company have a capacity of 2, 12 and 100 litres, and the volume of gas stored is 10 times their volume per atmospheric pressure, and thus about 100 times their volume at the pressure of 10 atmospheres which is normally employed.

At the factory the acetylene, prepared in a properly-constructed generator and carefully dried, is compressed in a pump, the two cylinders of which, quite separate from each other, raise its pressure to 3½ and 12 atmospheres, respectively.

At this pressure it passes directly into large storage cylinders full of porous bricks saturated with acetone. The cylinders which are supplied to the public contain similar bricks and are filled from these storage vessels.

The use of acetylene in this form obviates many of the troubles adherent to the direct generation from carbide; but, of course, necessitates the use of suitable reducing valves to insure a constant pressure of gas from the charged cylinders. The loss of acetone is comparatively small, only amounting to a few per cent. in each discharge.

The applications so far made have been chiefly to the lighting of tramways, railways, and for similar purposes in which field the acetylene industry has not generally been very successful up to the present time. Much success has also been achieved by the same company with an oxy-acetylene blowpipe which has found extensive application in the welding of iron, steel and other metals. The gases are mixed in the burner in the proportions, 1 of acetylene to 1.8 of oxygen, and in order to get the velocity necessary to prevent the flame striking back, the gases are fed in under a pressure of 4 meters of water, which is, of course, easily accomplished from the cylinders of dissolved acetylene. The temperature of this oxy-acetylene blowpipe is exceedingly high, being capable of easily fusing lime, alumina, silica, etc. By regulating the proportions of the two gases either an oxidizing or a reducing flame can be obtained, but for the welding of the metals it is of course advisable to have as neutral a flame as possible by employing the gases in the proportions given above.

The further applications of this ingenious method will be followed with interest, and its influence on the carbide industry should be of the most satisfactory nature as opening up many new uses for acetylene gas.

## THE PLANT AND PROCESS OF THE INTERCOLONIAL COPPER CO.

By Woolsey McA. Johnson.

The process of the Intercolonial Copper Co. for the electrolytic coining of copper presents several features of interest to electrochemists. Numerous attempts have been made in the past to produce electrolytic copper from a copper solution by leaching ore and electrolyzing against an insoluble anode. These processes have as yet met with but little success in competition with the old processes of mechanical concentration and smelting, of chlorination roasting and cementation on scrap iron, or of direct smelting, etc., several difficulties have arisen such as when sulphuric acid is used as solvent, its destruction by the lime and magnesia in the calcined ore,

Reduction Works of Intercolonial Copper Co.

etc. The solution must be regenerated with new acid at considerable expense. Power, coal, acid, labor and electrical machinery are expensive at remote mining-centres and change economic conditions.

The insoluble anode has also been a hard question to solve. Platinum is too expensive and will lose weight with time, carbon is useless in a sulphate solution. Even the best Acheson graphite electrodes disintegrated as anodes in a sulphate solution and in almost all leaching proposition we have sulphate solutions. Lead gives the well-known "Casparische Ueberspannung" and will wear out from peroxidation just as the storage-battery positive will age with time.

How these electrometallurgical and commercial problems have been met will be found in the following account of the plant of the Intercolonial Copper Co. at Dorchester, N. B., Canada, which I inspected in January, 1903. This plant has

produced one ton of electrolytic copper daily for six or seven months, and has sold this to Canadian brass founders as equal to the best brands of electrolytic copper. Careful analysis of the cost sheet of this large experimental plant by the company's officials have convinced them that electrolytic copper can be had down at tidewater for 6 cents a pound. The working of the plant in the past year has unquestionably brought the process beyond the experimental stage. The only criterion of the successful working of any radically new process is the production of the article in large enough quantities to be sold in market. This has been done in the past year and the process has been subjected to a large scale test.

The ore of the Dorchester mines consists of a chalcocite weathered to the green carbonate or oxide. The copper is found in a vast lenticular mass in conglomerate and sandstone beds belonging to the carboniferous age. The copper ore is often associated with the fossil remains of this age and is found replacing the fossils. Large masses are found, but usually the copper in ore will run from 2 to 4 per cent. About $200,000 has been spent in blocking out ore, and the company's experts claim to have 78,000,000 tons of 3 per cent ore in sight. This claim may be right, but the geology of the copper ore is so inconstant, as to make it uncertain.

This ore would be a difficult proposition to smelt, for it does not carry enough sulphur to render direct matting practicable, nor could such low grade ore be smelted to black copper at present prices of coke and copper. Besides the ore is too silicious for furnace work. In both cases, very foul slags would result. "Weathered" chalcocite is a hard mineral to concentrate by water and large losses in tailings would ensue.

The ore could be treated by the "Henderson" process with undoubted success if a small amount of pyritic ore could be purchased, but it is doubtful if it could do better than the present process. The very small values in precious metals are

FACE OF TUNNEL, SHOWING COPPER-BEARING SEAMS.

lost by both these processes. I believe that the Henderson process has been worked with crude $Na_2HSO_4$ with good success, and this process could be made practical in this way.

Dr. N. S. Keith has a process to reduce at low red heat the copper in a carbonate or roasted ore. He mixes the ore with a small percentage of powdered coke and reduces it to small particles of metallic copper in a "Chase" roaster. The particles of metallic copper are separated easily by reason of high density by some mechanical concentrator.

Neil's $SO_2$ process is being worked successfully in Arizona. This, as is well known, consists in dissolving the copper in a solution containing an excess of $SO_2$ and precipitating it by boiling out this excess.

The Carmichael process meets the commercial conditions better than any of these for the following reasons:

1. Low lime.
2. Cheap coal, $3.65 per ton at firebox, as the plant is 4 miles from tidewater, near Nova Scotia coal mines.
3. Cheap mining.

The ore from the stopes is mined into chutes, wherever possible. These chutes lead to ore bins which empty directly into small tramcars. The cars run by gravity down the inclined tunnel and dump automatically into the ore bins before the

BATTERY OF CARMICHAEL ROASTERS.

crusher. The situation of the mine on top of hill renders tunneling practical. The ore is crushed in a Buchanan crusher and then carried by elevator to screens. The coarse from the screens goes to reducing rolls, thence back to screens, repeating the operation until the ore is 20-mesh fine. From the screens the fine ore drops to large ore bins. From the ore bins it is fed by screw conveyors into a battery of 15 Carmichael roasters. These consist of long tubes of cast iron passing through a fire-brick muffle, heated by a flame from the fire box. The first part of a roaster is a brick-lined drum. All revolve, and the ore is first partially desulphurized in brick drums. The ore next passes to the iron tube where it is dead roasted. Any lime is now sulphated and the iron is changed to the ferric state. The roasted ore from the revolving drums is carried by a chain conveyor directly to lead lined bricked vats of 20 tons capacity.

These roasters are efficient but are liable to break down, of small capacity, and a furnace man would say, cause too much "fuss and bother." Units turning out 2 to 3 tons are not in fashion in America now. The old White-Howell roaster is of similar design, but has been long given up. The ore could be more easily and cheaply roasted in a Brueckner, or, if a continuous working furnace was required, in the old-tried Brown, or the promising new roaster of Capt. Chase. There are other well known roasters that could be used if necessary, such as Davis, Pearce turret, or even hand raked reverbera tory.

The hot ore falling from the conveyor drops into a 5 per cent. solution of $H_2SO_4$. The solution of the copper takes place rapidly. This is an old and well-tried reaction that works well on a large scale. The "made solution" carrying 2.5 per cent. Cu and considerable free acid is drawn off to the "storage" vat. The fact that there is left in the solution this free acid, makes a 95 to 98 per cent. extraction a practical proposition. The tailings assay lower than 0.10 per cent. Cu. This is a strong point of the process, as the solution of the copper is slow when the copper grows high and the acid grows low.

The solution is drawn off, pumped to storage vat and impregnated with $SO_2$ gas (made by burning brimstone in an

iron pot (under blast) in the storage vat. The electrolyte runs down from the storage vat to the plating vats which are arranged in cascade. Sulphur dioxide is also blown through the electrolyte in vats by means of perforated hard rubber tubes. This bubbling of the $SO_2$ is desirable for the following reasons:

1. It makes good "top-bottom" circulation.

2. It protects lead anodes from peroxidation. Sulphation will occur in time.

3. It adds $H_2SO_4$ replacing that used in neutralizing small amounts of CaO. Practically, the acid is made at a cost of $6 per ton $H_2SO_4$—100 per cent.

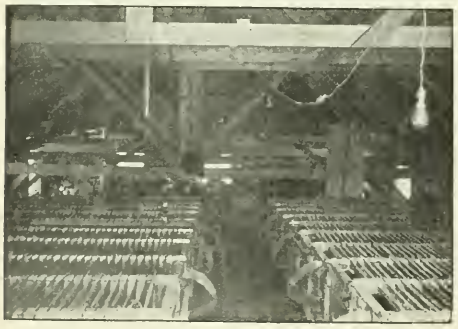
4. It acts as a depolarizer and reduces voltage of vats, and consequently amount of power necessary to deposit 1 ton of Cu.

This part of the process is old, in fact first patented in 1878 by an Englishman. It has been repatented several times in many countries, although it is quite doubtful if the Chinese or Fiji Island patents are valid. I worked out this electrochemical reaction independently some years ago, as follows:

$$4\,(+) + \overline{\overline{SO_2}} + \overline{\overline{O}} + H_2O = \overset{++}{H_2} + \overline{\overline{SO_4}} + 2\,(+)$$

where the + and — in paranthesis and the + and — over the chemical symbols represent ionic charges.

This reaction with lead or platinized platinum anodes proceeds in accordance with Faraday's law. As there is a union



ELECTROLYTIC ROOM.

of positive and negative charges, the free energy necessary for electrolysis is less than if no $SO_2$ were present. In other words the $SO_2$ acts as a depolarizer. My idea had been to use this for $H_2SO_4$ production in connection with an electrolytic refining plant which was proposed by my employer. This idea is, of course, also old. It is merely mentioned as one more illustration of the fact that different minds often produce the same solution of problems. The last man to re-invent this reaction is C. J. Tossizza, of Paris, who patented it in the United States, September 30, 1902.

The copper is precipitated at the Intercolonial plant at 1.5 volts, 6 ampères per square foot, electrodes of lead about 1½ inches apart. The current efficiency is about 90 per cent. The cathodes are greased and graphitized. The cost of power would be from $25 to $30 in the present small generating plant. This is more than cost of "cementing" on scrap iron, but the product is worth at least $30 per ton more than 80 per cent. "cement copper." Besides the solution is easier in this process, because the copper can be thrown down from acid solution, while in the "cementation" process free acid means just so much more iron used before the copper is thrown down.

Using wood at $1 a cord, or coal at $4 a ton in "Loomis-Pettibone" gas producers with Westinghouse gas engines to generate power, as is done by Phelps, Dodge & Co., in Mexico and Arizona, the cost would be much lower, probably as low as $8 to $9. Water-power might reduce the cost of power to $5 or even $2, as a low figure.

The electrolysis is conducted until the Cu content is reduced from 2.50 per cent. to 1.00 per cent. The solution regenerated in acid by anode and cathode reaction is not subjected to further electrolysis, but is used for leaching new ore. This is another skillful use of electrochemical knowledge, as the removal of the last 1 per cent. of Cu would be very expensive, because of decreased current efficiency.

The ore when leached is washed and sluiced by water from the mine which is on a higher level than the electrolytic plant.

This process is a good verification of the prophecy made by the English electrochemist, Mr. Bertram Blount, on page 88 of his "Practical Electrochemistry:" "That it (electrolytic winning of copper) will be achieved in the near future is probable enough. . . . What is wanted is not so much a totally new device as a well-schemed plant embodying perhaps nothing but what is common knowledge, but planned so as to be fairly permanent as a whole and with its perishable parts easily and cheaply renewable."

The estimate of the company is as follows:

| | | |
|---|---|---|
| Value of 57 pounds of copper at 12 cents per pound, | | $6.84 |
| Cost of mining and delivery to mill, per ton | $1.50 | |
| Cost of milling, per ton | 2.00 | |
| | | 3.50 |
| Net profit, per ton | | $3.34 |

"These figures, based upon a comparatively small tonnage, bear out closely the early estimates of Prof. Carmichael on the cost of producing copper here, and are believed to be conservative. It is therefore apparent that the plant as at present constructed, running to its full capacity, will show substantial earnings on the capital stock issued, while it is obvious that the operation of a large plant treating 1,000 tons daily, for which the ore supply is believed by our engineers to be ample for a long term of years, will establish this enterprise as a great and permanent mining industry.

"The mining and development work of the company has been under the supervision of L. S. Griswold, M. E., of Boston. The process for treating the ore and the plant are the design of Prof. Henry Carmichael, of Boston."

If the plant and process do not develop into a commercial-paying proposition it will be in my opinion either because 3 per cent. ore cannot be found or because the lime and other soluble impurities increase to too high a figure, or because of unexpected financial trouble. The process is certainly well suited to treat ore of this character. Low copper, high lime, or lack of capital would of course cause a failure.

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Output of Electrolytic Refineries.—Mr. Titus Ulke kindly informs us that since he sent us his article "Notes on the History of Electrolytic Copper Refining in America," published in our last issue, he has received subsequent returns from several refineries, which change somewhat the statistical figures given in his article. The corrected figures are as follows: The total daily copper output is 764 tons, or 279,000 tons per year. At the same time the amount of silver and gold recovered per year in the electrolytic copper refineries is 27,000,000 ounces of silver and 346,020 ounces of gold.

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From reports of the Treasury Bureau of Statistics it appears that the copper exports of the United States consist chiefly of electrolytic copper. Their value was $33,534,899 in 1901, and $45,485,598 in 1902. The number of electrolytic copper-refining plants in the world, either now in active operation or ready to start operation, is 33, of which 10 are in the United States, 9 in Germany, 6 in Great Britain, 4 in France, 2 in Austria and 2 in Russia.

## THE ELECTRIC REDUCTION OF IRON ORES AND THE CONVERSION OF IRON INTO STEEL IN AN ELECTRIC FURNACE.

By Louis Simpson.

When Sir Henry Bessemer first brought his invention before the notice of the steel manufacturers of Great Britain, both he, and his invention, did not receive, at their hands, the attention and consideration that has since been proved the invention warranted.

It was only when enterprising capitalists advanced the money necessary to operate a works, wherein steel was manufactured under what is now known as the Bessemer process, that the steel makers of Great Britain began to investigate the process, and eventually applied for licenses for rights to manufacture.

History is ever repeating itself. It is not surprising that the steel makers of to-day have looked with scepticism upon all of the several processes now available, of electric reduction and conversion, although certain of those processes have reached practical development and are here to stay.

One cause of their want of interest is probably due to the fact that, in the past, the advocates of the electric furnace have not shown unanimity in advancing the best claims of this process and have at times claimed that which could not be sustained. They have too often so spoken and written as to raise doubts in the minds of practical steel manufacturers, even in some instances to the extent of "damning by faint praise." At the Niagara Falls meeting of the Electrochemical Society, Mr. Salom stated that in his opinion: "There is not much danger, in the immediate future, of the electric furnace superseding the blast furnace, as a method of manufacturing iron or steel, *although the possibilities of it are not to be ignored in the future.*" This remark would suggest the thought that whilst the steel manufacturer may for the present ignore the possibilities of the electric process, yet it would be well for him to give it attention, lest some fine morning he might wake up to find that, whilst resting in fancied security, some competitor had captured part of his business by the aid of the electrical process. Other speakers expressed the opinion that the electric furnace for iron and steel "has the very great handicap of high cost." The report published in The Electrochemical Industry is herein quoted. It is, however, not clear whether the "high cost" referred to is intended to mean a supposed high cost of working or to a supposed high first cost of erecting a furnace.

Mr. E. R. Taylor, at the same meeting, claims that "he could now construct a continuous electric furnace that would dwarf the largest blast furnace in existence." Mr. Taylor has been very successful with his furnace, which he uses for the manufacture of carbon bi-sulphide, and there would seem to be no reason why the same furnace with modifications should not be used for the reduction of iron ores. But for the fact that Mr. Taylor's electrical plant is of insufficient capacity, his type of furnace, long ago, would have been tested as to its possibilities in the reduction of iron ores. In The Electrochemical Industry's issue of February, Mr. Marcus Ruthenburg claims that through a furnace of his invention "iron ore can be reduced at a cost of 500 kilowatt hours per ton."

Few of those who have written on this question have published statements that would appeal to the practical manufacturers, that is to say, those who have made it their business to know something about the cost of power production, of electricity and of steel making.

Some of these writers even lessen the value of their opinions upon the possibilities of the electric furnace, by making statements upon some side issue, which statements being obviously open to criticism, causes the reader to doubt the correctness of the opinions and data given in respect to the electric furnace.

The commercial practicability of the electric process is a question of such a complex character that it is difficult for an expert of any one of the several branches of science interested to form a correct judgment upon the question, as a whole; unless he is posted in all the other branches, and further, unless he has considerable knowledge of the commercial end of the question. It is not sufficient that this question should be considered by an electrochemist, nor by an hydraulic, civil, mechanical or electrical engineer; it is not sufficient that it should be considered by a metallurgist. It is necessary that the question should be considered by a man of experience in the market for which the steel made by the electric process is intended.

To illustrate this Mr. James Swinburne, president of the Institute of Electrical Engineers in Great Britain, in his presidential address given before that Institute, stated as his opinion that water-powers were of no great commercial value. The fact so stated may be and probably is correct, if applied to Great Britain, but is not correct when applied to the continent of North America, and especially to the Dominion of Canada. The causes given by Mr. Swinburne as being the basis for his statement are not existent at or around a considerable number of the waterfalls of this continent. Had Mr. Swinburne been an hydraulic engineer, had he the information, and had his experience in hydraulic propositions equalled his experience as an electrical engineer, he would either not have made such a statement or else he would have been careful to have limited its application to certain European countries.

It is not necessary to claim that the electric furnace will supplant the blast furnace or cause a revolution in the manufacture of steel. The blast furnace will probably be used under certain conditions. The electric furnace will certainly be used when and where other conditions exist. Amongst these conditions, the proximity of the consuming market to the electric furnace is of an importance too great to be ignored.

It is now admitted that the quality of steel made through the electric furnace is equal, and it is a question if it is not superior to the steel produced by any other known process. The question at interest is whether it is possible to manufacture steel using the electric furnace at a less cost, or at the same price as can be done by other methods. To the cost of producing steel must be added any extra freight, over and above the average, which may have to be paid for conveying the steel from the steel works to the different consuming markets.

Of course, the cost of carbon, in whatever form used, and of electrical power, if used in place of carbon, is a considerable factor. It cannot, however, be claimed as being the only factor worthy of consideration.

It is always difficult to compare the cost of producing manufactured materials or goods, when the conditions, under which they are manufactured, differ widely. There is difficulty in ascertaining the lowest cost of producing steel by the blast and open-hearth furnace process. Up to date, although numerous small works are producing steel of good quality by the electric process, no works have been erected of a magnitude sufficient or under such favorable natural and local conditions, as would insure the most economical production. It would, however, be no argument to assert that steel cannot be produced at a certain low figure, because under the conditions existing at and around these several small plants, steel by the electric process is not being produced at a cost as low as it can be produced elsewhere under different conditions.

Certain data have been secured from the results obtained at certain of these works, which have produced steel of excellent quality. This steel has not been produced under the most favorable conditions, such conditions as are known to exist upon this continent, more especially in the Dominion of Canada. This data corrected to conform with the conditions indicated will give the possible cost of producing steel by the electric furnace where conditions are favorable.

The charges which together make up the cost of steel are as follows:

1 Raw material, consisting of (*a*) iron ore (assembled).
(*b*) Carbon (assembled), used to combine with the oxygen contained in the ores.
Carbon (assembled), used for heating or electric power used for heat.
(*c*) Limestone (assembled).
2 Labor
3 Repairs, renewals, taxes, insurance and depreciation.

To which must be added any excess of freight charges which have to be paid by the customer above the lowest existent freight charges.

The lowest known cost of producing steel ingots per ton by the blast and open hearth furnaces, have been stated to be as follows: It must, however, be remembered that the works were situated at a considerable distance from the chief consuming markets, therefore an unknown sum for excessive freight charges has to be added.

| | | |
|---|---|---|
| 1 | Iron ores (assembled) | $2.33 |
| | Loss in iron from pig to steel | 1.00 |
| | | $3.33 |
| | Coke | 3.77 |
| | Limestone | .30 |
| 2 | Labor | 2.50 |
| 3 | Renewals, repairs, depreciation, etc | 2.00 |
| | Extra freight | uncertain |
| | Cost of steel ingots at works, to which must be added cost of extra freight to consuming markets | $11.90 |

To-day the costs of iron ores, coke and labor have all advanced. At Pittsburg the cost of these items is considerably higher than quoted above, but the cost of excessive freight charges would in the latter case be unimportant. This question of excess in freight charges must always be borne in mind, but cannot be stated at any constant figure, it being ever a varying quantity.

Under conditions known to exist upon this Continent, more especially in the Dominion of Canada, the cost of iron ore and of limestone (assembled) as above stated may be considerably reduced, while the cost of labor is lower, as also the cost of repairs, renewals, depreciation, etc., when the electric furnace is used. For the local markets there would be a very considerable saving in the freight charges paid by the consumer. The total of these savings, in one case now under consideration would amount to over $3.50 per ton.

The lowest known cost of the carbon used in the blast and open-hearth furnaces, has been given as $3.77 per ton of steel ingots, this cost, however, cannot to-day be duplicated. The saving of $3.50 already indicated would permit the steel maker, when using the electric process, to expend upon the carbon, electric power and electrodes, the sum of $7.27 for each ton of steel ingots made, and yet the total cost would not exceed the lowest cost of production, under the blast and open-hearth furnace process.

According to data in the possession of the writer, steel ingots can be made by the electric furnace at a cost as low as $10.61 per ton, while the inventors of certain new electric furnaces, not yet tested practically, claim reductions in the cost of the process made in reducing the amount of electric power and of electrodes consumed, which, if correct would, in one case, amount to a reduction of $2.09 per ton, and in the other, to a reduction of 81 cents per ton, making the cost price $8.52 and $9.80 per ton, respectively.

There has always been great contention as to the cost of electric power. Calculations of cost have been based upon power costing $20 per horse-power year, because forsooth, that is the price charged by the power company at Niagara Other calculations have been based upon power at $15 per horse-power year, because another power company charges such an annual rental, while other calculations have been based upon the more reasonable rental of $10 per horse-power year, but for a reason no better than that possessed by those who used $20 per year, as a basis for their calculation. One expert condemns employing hydraulic power wherewith to generate electric power, and claims that electricity can be generated from the combustion of soft coal at a price that will put "water-power in the shade." This expert claims that 500 kilowatt hours can be produced by the combustion, *under a steam boiler*, of 1,000 pounds of soft coal.

It is unnecessary to point out that up to date it has been impossible, *under ordinary continuous working condition*, to produce 500 kilowatt hours by the consumption of 1,000 pounds of any kind or quality of coal, burned under any kind of steam boiler. Nor is the quantity of coal consumed by any means the sole expense in producing steam, by the combustion of coal. Wages, repairs, oil, depreciation, insurance, packing, etc., must be accounted for.

When a power company leases electric power at the rate of $10 per annum, such rental is not necessarily the cost of producing electric power. In most, if not in all of these power companies there is more water than that which flows or has gone over their water falls, and in any case the annual rental not only includes the cost of operating, of maintenance and of depreciation (the actual cost of the power), but also an amount necessary to provide for interest upon a large bond issue and further the dividends to be paid upon a large issue of stock, much of which is made necessary by the presence in their stock of the water, that never went over the falls.

Under favorable conditions electric power can be produced for less than $4 per electric horse-power per year.

There are certain important advantages which may be claimed for the electric process over the blast and open hearth furnace process They are as follows:

1. The steel produced is more compact, it is more regular in quality.

2. In the same works, and that of no great magnitude, different qualities of steel and of steel alloys can be produced and that at a minimum cost.

3. Providing power has already been developed the output of a works can be quickly increased. The works can be closed down without damage to its furnaces, and it can be restarted at a day's notice.

4. Up to the ingot, no skilled labor is required other than the electricians and metallurgists.

5. The cost of the developed power is balanced by the reduced cost of the furnaces.

6. Less loss in output. No closing down of works because of repairs being required to the blast furnace. The cost of the electric furnace is so low that it permits of the erection of one or more extra furnaces, which can be quickly run into commission should any of the furnaces then in work require repairing.

It is claimed that by the electric furnace steel can be produced:

1st. Of a quality as good as, if not better than can be produced by the blast and open-hearth furnaces.

2d. There are no disadvantages connected with the electric process.

3d. There are several important advantages connected with the process.

4th. Given the existence of certain natural conditions, which will be indicated, the steel so made can be produced and delivered to certain markets at a price as cheap as, or cheaper than the steel produced by the blast and open-hearth process when delivered to the same market.

The natural conditions referred to, part or all of which should be present, are:

Low-priced iron ores of high grade and good quality.
Low-priced limestone.
Low priced electric power, however generated.
A nearby consuming market.

## DEFECTIVE MACHINE INSULATION.*

By C. E. Farrington.

The best excuse for a discourse on the defective insulation which is found in modern dynamo and motor construction is the statement that it is the greatest obstacle to electrical development at the present time. It is a fact beyond controversy that the electric motor is not being used as much as it would be if it were a more perfect machine. A veteran railway superintendent whose title was once "barn boss," recently told me how much he wished that he could have as little sickness in his motors as he used to have among the horses.

My connection with the manufacture of electrical insulation was brought about through the request of a large electrical manufacturing company for a substitute for shellac as an insulating varnish. This was some ten or twelve years ago, when all that any paint and varnish chemist knew about insulation was what he might derive from the examination of a dictionary, so we asked our electrical friends for full details of the work an insulating varnish had to do. The answer, signed by one of the best known of the large construction concerns of a dozen years ago, is in my possession to day and reads: "An insulating varnish must contain as little water as possible and dry quickly. We cannot give you further details, but if you will make the varnish as above stated we will make the tests to see whether it has any insulating properties."

If such an answer had been rendered on any other point concerning mechanical or electrical engineering it would have been considered a glaring admission of ignorance and no large electric company would have tolerated such ignorance after it had once exposed itself. But it is a fact that electrical engineers have neglected to use the methods of applied chemistry in this most important item of their work. They have cheerfully gone on and on, jauntily ignoring well known chemical laws and trusting to the cleverness of their sales departments to shift to buyers the responsibility for losses and annoyances which might be wholly avoided were conscientious study made of the problem.

By our inquiry we finally ascertained that shellac varnish (gum lac dissolved in alcohol) gave the best results of anything which they had then used, but that electricians were quite well aware that it was defective. As no further information was forthcoming, we proceeded to make a very rapid drying copal varnish which was duly submitted to our electrical friends, and after a few days' test it was adopted by them and its use commenced in considerable quantity. It was the first insulating varnish ever made. As an illustration of what we have learned since then I will say that no competent engineer will now concede that a given compound has any insulation value whatever until his tests have been those of actual service under widely different conditions, and unless the time test is at least a year.

We submitted samples of our insulating varnish to several other electrical concerns and invariably received flattering testimonials as to the wonderful insulating properties which it possessed. We gave it the name "insullac," and I think during the next six months we unintentionally crippled as much machinery as we insulated. I think the record which we made at that time has been equaled once or twice since by some of our enterprising competitors. But in justice to them I must say that they were guided by just the same sort of advice as we had. The experience of that six months produced a profound impression. Savage complaints convinced us that the testimonials of our electrical friends were better testimony of their ignorance of the chemistry of insulation than of the quality of the material whose praises they sang. Our surprise and regret were superseded by an ambition to atone for our error, and we determined to learn something about the subjects for the benefit of those whose injury we had unwittingly assisted in.

It is my pleasure to outline here the course of study which was opened by this investigation. It was primarily necessary for us to define the exact function of a varnish in and on the coils or windings of a dynamo electric machine. Why should a varnish be used at all? Solely because there has never been an insulating fibre produced which did not need some sort of reinforcement which could obviously be best applied in the form of a paint or varnish. Motors will not run, even in very dry situations, unless some protection in the shape of varnish is applied. We asked electricians for an explanation of this they told us that water got into the machines if varnish was not used. When this answer was applied to street railway motors running on submerged tracks or on motors unprotected from street spattering, the explanation seemed to be adequate, but its adequacy was completely lost when we applied it to stationary machines running under fairly good conditions.

Surely the insulation resistance of the varnish is not required to enable the machine to run. There probably never has been a successful machine designed wherein the difference of potential between windings was equal to 10 per cent. of the insulation resistance of the ordinary double-cotton covering which was used on those windings. This covering has an insulation resistance standing about 200 volts a c, and it is obvious that if that resistance could be made constant there would be no necessity for the reinforcement of machine insulation with anything in the line of paint or varnish. In other words, any paint or varnish which is used on magnet coils is used in the hope of making constant the initial insulation resistance of the cotton covering.

It being plain that the function of any varnish or paint which is applied to a motor or dynamo coil is to reinforce the cotton covering we must study the weaknesses of the cotton in order that we may know how to correct or help them.

The first defect of cotton is the fact that it cannot be spun to a commercial profit unless it carries from 5 per cent. to 15 per cent. of water, but at the same time our attention should not lose the fact that this water does not interfere with the average insulation value of cotton covering as indicated by mere laboratory tests. The trouble which the water makes is accomplished when it turns to steam under the heat of the machine, or when it travels from the core out through the coil under the influence of rotary motion, leaving innumerable passages and openings where the electric current may follow.

Another material defect of cotton is the ease with which it becomes carbonized, but it is only fair to say that the carbonization of cotton covering is largely offset by the resistance gained from the expulsion of moisture as an armature becomes dried and seasoned.

The third defect of cotton is the acid which it carries and which assists its impregnation with copper oxide.

Determining that the best insulating material must be the one which would reinforce these weaknesses of cotton, we assembled all the materials commercially available for the manufacture of compounds which might be applied to coils of copper wire by dipping or with a painter's brush and began the work of systematic search for the qualities which would enable these materials to accomplish the necessary results. In this connection every varnish gum, every treatment of drying oils, every combination of waxes, pitches, asphalts and gum substitutes, including the cellulose compounds, were brought under our tests.

The first test of all was to see whether a material had a melting point or a viscosity or a combination of both which would enable it to stay in a badly overheated coil. This point brought out a curious inability on the part of a good many electricians to distinguish a difference between old-fashioned tests and modern conditions. They wanted to test insulation melting points by the same method by which oil chemists

* A paper read before the Franklin Institute of Philadelphia on March 12, 1903. Mr. Farrington is chief-engineer of the Massachusetts Chemical Co., of Boston.

find the melting point of an oil or a wax, but we found that test so misleading as to make it necessary to make our tests exactly like the conditions of actual service. We wound a coil of double cotton-covered wire about a steel rod, saturated the coil with insulating compound, withdrew the steel rod, inserted in its place an ordinary thermometer, put current through the coil via water resistance until the coil was so badly heated as to give off dense volumes of smoke, and if by weighing we found that a coil did not lose more than 10 per cent. of its compound we decided that such material would stand hot service in overloaded machines. An insulating compound should have such a high melting point. The designer of a motor never can tell which one of his machines will be located in the hottest corner of a rolling mill, or whether his generator may not some day have to stand the heat of a torpedo boat engine room with the ventilating apparatus broken down, or an emergency overload in ordinary practice.

The tests to determine the capacity of a given insulating material to exclude moisture from the coils of an idle machine were chiefly a process of elimination, and here we found aid from the experience of varnish and paint manufacturers, and in the researches which have been made concerning the materials which enter into their products.

We first eliminated shellac for the reason that it could only be made into a successful varnish by dissolving it in alcohol, or alcohol and water. You can make a shellac varnish totally devoid of water, but you cannot do it commercially, and if you could you could not keep it so, as the alcohol in shellac varnish rapidly attracts moisture the moment it is exposed or applied.

The copal varnishes and asphalt varnishes were eliminated at this point, as we found that the heat and vibration of magnet coils quickly reduced them to a powder or cracked their films so badly that they could not exclude water any more than a sieve could hold it.

For some time we thought that linseed oil might be so boiled that it would effectively exclude moisture. We were attracted by its high initial resistance and the extremely tough film which could be obtained from varnishes composed of it, but here again we were stopped by the accumulated facts which experienced varnish and paint makers furnished us. Linseed oil is a commercial commodity solely because of the rapidity, as compared with all other oils, with which it absorbs oxygen. A method of arresting the oxidation of a film of linseed oil at any desired point would be of immense value to the electrical fraternity. We cannot hope to arrest the oxidation of a film of linseed oil at any particular point. It continues to oxidize until it becomes a brittle, cracked and utterly defenceless mass, so far as its capacity to prevent the passage of any stray electric current is concerned. More electrical apparatus have been reconstructed or repaired because of the oxidation and other defects of linseed oil than of all other causes put together.

A great many electricians like to claim that their apparatus is well ventilated. "Well ventilated" also means well oxidized. There are very few armatures which are not well ozonized also.

When the wearer of a black coat leans against the white trimmings of a house which was painted with linseed oil and white lead last spring, he has to dust himself off, simply because the oil which should have held the pigment to the house has been totally destroyed by atmospheric action. It is because of this quality of linseed oil that we are compelled to have a varnishing day in our art galleries, and it has never been disputed that thoroughly oxidized linseed oil is not only soluble in water, but is hydroscopic, since that fact was established many years ago by eminent German authorities.

We had to consider that an insulating compound might be used some day in a generator located on top of a steel penstock in an isolated power house where there was no heat, and that when the generator should shut down it would attract moisture at a tremendous rate by condensation. It would not run a week under these conditions if it were insulated with a linseed oil preparation. It is well known that a series of chemical actions may take place in an electrical machine, wherein linseed oil may be found wholly responsible for the presence of water even before the oxidation of the oil has reached the advanced stage. This occurs when an atom of hydrogen in the oily acids of the varnish is replaced by an atom of copper. The ejected atom of hydrogen selects a pair of friends from the oxide on the wire and thus produces water. Only one material was able to pass these tests for the exclusion of moisture under practical conditions, that being the high melting point paraffin compound whose widely successful use has brought to me the honor of delivering this address.

A particular point which led us to the adoption of this material is its capacity to withstand high temperatures for a great length of time and still maintain its original plastic condition. The vibration in a high-speed armature probably equals that in any mechanical device when the shattering jars of gear connections are taken into consideration and when street railway machinery is added to the list of apparatus under consideration.

The expansion of armatures and field coils as they heat and their subsequent contraction when the loads are removed are obvious and consequently any insulation which does not have permanent plasticity under heat is wholly defective for this sort of electrical insulation. Consequently a large list of materials composed of varnish gums and linseed oil, asphalts, etc., were eliminated one by one as they showed their utter incapacity to stand the shattering influence of this vibratory stress.

The defectiveness of the first material which we ever made was caused wholly by the presence of varnish acid. As is well known to varnish chemicals, all of the varnish gums are acid bodies. Indeed, it is safe to say that there is practically nothing in the shape of gum or oil which enters into varnish that is not an acid body. The question then arose "How far is anybody warranted in introducing acid into the vitals of high-cost apparatus?" Of course the answer is, "Just as little as possible," but I am sorry to say that a good many electricians have declined to give this point the consideration to which it is entitled, and they have thereby become responsible for a great deal of the apparatus which has proven defective. Of course I am familiar with the claim of some electricians that they "never have any trouble with apparatus built by them." In the first place we know that such a statement is not true, and if it was true, it would not be a good reason for deliberately disobeying physical law.

From one end of this country to the other you can go in the street railway field and find apparatus which has gone to the scrap heap chiefly because it has been insulated with defective insulation. Within a year one of the largest generators in the world has had its armature twice rewound because it was insulated with defective insulation, and on the third trial its builders repaired it with the same stuff which first short-circuited it. The money loss in that instance is already close to $10,000, with more to follow. There is not a central station manager in the United States who has tried to sell power who has not come into contact with a manufacturer or a machine shop superintendent who told him he would not put in a motor unless the central station man would guarantee against his shut-down losses and against repairs. Printers have discarded electric motors for gas engines because they say the gas engines have a reliability which motors have not.

Every defective electric motor is an argument for the sale of an engine in its place, and it is only so because the motor manufacturers have neglected in their rush to keep up with commercial progress to give to their insulation the same care and thought which the engine builders have given to their construction. The same processes of elimination which keeps poor metal out of piston rods will keep poor insulation out of armature coils. But at present manufacturers will not seek

such improvement until consulting and operating engineers insist upon it.

The obvious unfitness of linseed oil for motor insulation, because of its acid composition, is best explained by reference to indisputable authority. What everybody knows "is most indisputable authority," and anybody who knows anything about chemistry knows that an acid is a body which will attack metal. An acid is a body which attacks copper. An acid is a body which will combine with copper to produce a third and possibly a fourth material. Users of shellac, copal varnish, and linseed oil varnish as insulation have frequently found that the cotton covering of their wire has been turned a brilliant green, which is a universal symptom that the copper has been attacked by an acid. When we said that such a symptom was a bad one some electricians argued with us and said they didn't think we had any authority for that statement and that it didn't make any difference if a coil did turn green, provided that coil was properly baked out. They declined to accept what every chemist knows. We have given considerable thought to this matter and have come to the conclusion that a green coil is an evidence of bad construction, is *prima facie* evidence that a radical chemical change has gone on within precincts whence chemical changes should be excluded with great rigor.

Green discoloration is evidence of inconstancy where constancy is indispensible. As it is very seldom seen except as a relic of a broken down machine, it may therefore be said to be coincident with burned-out and short-circuited machines. But this discoloration becomes more potent in its suggestiveness as we consider what takes place to produce such a radical, physical change—a change visible to the naked eye, a change positive and far reaching enough to send the green coloring matter through mica 1-16-inch thick, and to impregnate thick wrapping paper and fibre stock. In the study of this action we need accept nothing but the facts and authority which are beyond dispute by being common knowledge. When we see a piece of mica that was once a beautiful amber color turned green, when we find that it would stand a puncture strain of 10,000 volts while amber color and can be punctured with 1,000 volts since its color has been altered, and we find that it has actually failed to prevent the passage of a current of not over 10 volts, we have a right to conclude that there is a relation between such green discoloration and coincident drop in insulation resistance, and we have a right to carry that conclusion a step further and decide that the short circuit was caused by the chemical transformation of which the color change is evidence.

At least we are justified in a further exploration and examination in the light of the simplest variety of information on a simple chemical action. By so doing we find that it is easy for a varnish to have a chemical effect upon copper. Such action is the rule, rather than the exception, and now by reference to well known authority we find that this green action is the characteristic one of acids upon copper. The presence of acids near copper is always evidenced by green discoloration. Vegetable acids substitute atoms of copper for atoms of hydrogen in common with other acids. We are justified in concluding that such substitution of copper for hydrogen takes place in a gaseous or semi gaseous state. We shall now be able to apply the knowledge that vaporized copper has a high conductivity and we shall then come to an unassailable conclusion that during the time when that mica was being impregnated with that vapor or varnish-copper the insulation of the mica was so reduced that an easy passage was afforded to the 8 or 10 volt current which effected the short circuit.

When we find that the green discoloration may take place in an idle machine and not short circuit it and that short circuits always appear when the green discoloration takes place in a machine which has been constantly in operation, we obtain further proof of a positive nature that acids should not be permitted to enter into coil construction under any circumstances. Not even when they are loaded with black coloring matter to cover up their corrosive action.

In this connection we exploded one of the "Mother Goose" melodies or superstitions of the electrical fraternity, the foolish notion that lubricating oil caused short circuits. Lubricating oil never will, never did, it never can cause a short circuit. If we could design a generator which would run in oil, immersed in oil just as transformers are built, we should undoubtedly produce a successful machine. Why, then, should lubricating oil cause a short circuit? The first electrician who had a short-circuited machine was naturally disappointed and wanted an excuse, and when he found that lubricating oil had penetrated into the coils he accused it of causing the trouble. What actually occurred was this. The lubricating oil came in and stirred up the dormant or satisfied acids of the varnish which he had used. Varnish makers who have essayed to manufacture insulating compounds have on several occasions claimed that their varnishes were oil-proof. This was nothing but a joke, however. Varnish salesmen sometimes attempt to prove that an insulating varnish is oil-proof because they can coat a newspaper with it and the newspaper will hold oil in the open air and away from the heat of operating apparatus. As a matter of fact varnish which is so proved to be oil-proof will unite readily with lubricating oil under a temperature of 150 F. The trouble is that it will not unite homogeneously. The oil unites with one part of the varnish and separates that part from the balance of the varnish so that there are two or three separate and distinct bodies where there was originally but one. In one or both of these the acids are now unsatisfied and they immediately attack the copper, and as before described cause the short circuits which were attributed to lubricating oil.

The oil was absolutely innocent. It is absolutely indispensable and the acids of acid insulations are not indispensable.

Inasmuch as it is feasible, by working in the paraffin series, to make non-acid insulating compounds which have complete chemical affinity for lubricating oil it is perfectly easy to obtain insulation for a machine which will be friends with and welcome all the good insulation which may soak into it from its bearings in the form of oil.

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American Electrochemical Society.—At the meeting of the Board of Directors, held in Philadelphia on March 5th, the following-named gentlemen were elected members: A. S. Garfield, Paris, France; Louis S. Cates, Parral, Chir, Mexico; Lee Shepherd, Midland, Mich.; John L. Clawson, Philadelphia, Pa.; F. J. Davis, Lockport, N. Y.; John J. Riker, New York; W. R. Mott, Madison, Wis.; C. F. Carrier, Jr., Bethlehem, Pa.; H. M. Backus, Bayonne, N. J.; J. M. Aylsworth, East Orange, N. J.; E. N. Dickerson, Stovall, N. C.; William Battle Phillips, Austin, Texas; C. R. Walker, Cambridge, Mass.; Walter G. Graves, Cleveland, Ohio; Albert Finck, Cleveland, Ohio; D. R. Warmington, Cleveland, Ohio; C. F. Mabery, Cleveland, Ohio. The following gentlemen were elected at the meeting of the Board of Directors, held in Philadelphia on April 4th: J. T. Morehead, New York; Thomas A. Edison, Orange, N. J.; H. A. Skelton, Foyers, Lockness, N. B., England; Geo. F. Seward, New York; William B. Rankine, Niagara Falls, N. Y.; Van Rensselaer Lansingh, Chicago, Ill.; Augustus E. Knorr, Baltimore, Md.; Richard Threlfall, Birmingham, England; Otis E. Acker, Niagara Falls, N. Y.; Samuel Newton Smith, Minneapolis, Minn.; B. H. Hite, Morgantown, W. Va.; Edward F. Kern, Lansingburgh, N. Y.; Charles H. Moritz, Niagara Falls, N. Y.; Walter A. Wood, New York; George H. Benjamin, New York; Charles Baskerville, Chapel Hill, N. C.

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

By Carl Hering.

## INDUSTRIAL ELECTROCHEMISTRY.

*Electrolytic Refining of Copper.*—A very good summary of the progress made during the year 1902, especially in the United States, is given in the *Eng. and Min. Jour.*, March 14th, in an article by Ulke. The great lead of this country is shown by the fact that of the world's average daily production of electrolytic copper which is about 883 short tons, 764 tons or 86.5 per cent. are supplied by the United States; of the balance of 13.5 per cent., Great Britain furnished a little over 8.8 per cent., Germany about 2.75 per cent. and France a little over 1.6 per cent. The United States now produces electrolytic copper annually at the enormous rate of 278,850 tons, which at $260 per ton, is valued at $72,503,600. The copper exports of the United States consist chiefly of electrolytic copper, and for 1902 alone represented a value of $45,485,598, as compared with $33,534,899 in 1901. The value of the exports of copper was exceeded only by the value of the exports of manufactured iron, steel and mineral oils. There are now in active operation, or ready to be placed in commission, 33 electrolytic copper refineries in the world, not including the plant of the Osaka Electrolytic Refining Co., now being constructed at Osaka, Japan. During the past year there has been a notable increase in the quantity of concentrates from the Michigan or Lake Copper Mines, cast into anodes and treated electrolytically. As all Lake copper carries silver to a very noticeable extent, the author thinks it is only a question of time, when all the fine copper produced in the United States will be made electrolytically. It is possible that an electrolytic refinery for treating the converted copper produced on the Pacific Coast, will be built in Puget Sound, where water power is available in large units. The author says that the numerical coefficients in Philip's formulas for area, output, power, cost, current density of copper refineries (see Synopsis, September) are not valid for the conditions in the United States, and should be largely increased, being in most cases made fully twice as large. European refineries seldom use current densities exceeding 10 ampères per square foot of cathode surface; the average density employed in the 23 European refineries is less than 6 ampères per square foot. On the other hand, more American refineries use very high current densities. At Great Falls, Mont., with anodes comparatively low in silver, arsenic and antimony, and with cheap electric power generated from water, current densities up to 45 amperes seem to yield good copper at a profit. Under otherwise favorable conditions, therefore, the profitable use of high current densities, in order to enable the refiner to turn out copper at a very rapid rate, is seemingly limited solely by the excessive losses of current through heating, or boiling of the electrolyte, which occur with current densities above 45 or 50 amperes. Several custom refiners are now casting the anodes very thick and heavy, about 400 pounds in weight, as compared with 180 or 200 pounds, as in former years, partly because the percentage of scrap copper produced with the heavy anodes is only about one-half that with light anodes, say 7 per cent., as compared with about 15 per cent., the weight of the scrap filling being approximately the same in both cases. The American Smelting and Refining Co. are introducing in their Perth Amboy plant the essential features of the Ottokar Hofmann method for the purification of foul electrolytic solution. This process requires the electrolyte to be first neutralized, which is done by adding to it cupric axide (roasted copper matte), the bulk of the solution obtained being increased. This increase may be worked off in two ways, either by treating the surplus solution in a separate system of tanks in which lead anodes and cathodes are used, copper being recovered, while sulphuric acid is set free and used to acidify that part of the electrolyte which is returned to the refinery; or by making blue vitriol, in which case, of course, sulphuric acid must be bought for addition to the refined neutral electrolyte. The author gives a statistical table of the copper refineries of the world.

*Artificial Graphite.*—The manufacture of graphite electrodes does not seem to have been so large in 1902 as in the previous year, due to the fact that there were fewer new works equipped with such graphite; but the total number of works in which the artificial graphite electrode is used, seems to have increased, as certain valuable properties have been recognized which were not fully appreciated before, such as the resistance of graphite electrodes to oxidation when heated in the air, its high electrical conductivity, and the ease with which it can be machined. In a summary of the artificial graphite industry in 1902, by Fitzgerald, published in the *Eng. and Min. Jour.*, March 28th, he discusses this subject and gives other matters of interest in connection with this industry. A new method for graphitizing electrodes has been patented; the electrodes are placed in piles in an electric furnace, the piles being separated from one another by spaces filled with a "material having a lower co-efficient of electrical conductivity" than the electrodes; the current is then passed through the mass with the result that most of the heat is developed in the material which is in the spaces between the electrodes; the advantage of this method is that large furnaces can be used and yet the resistance can be kept sufficiently high to avoid the use of currents of very high ampèrage. A new process of making graphite in other forms has been patented which is based on metallic vapors acting upon amorphous carbon at the high temperature of the electric furnace. The amorphous carbon, such as the substance obtained from the distillation of petroleum oil, known as "petroleum coke," is placed in a furnace and mixed with a metallic compound, such as ferric oxide; extending from one end of the furnace to the other is a core composed of carbon rods or plates which act as a conductor for the current; on passing a current through the furnace, the petroleum coke is heated to a high temperature, the oxide of iron is reduced and the vapor of metallic iron acts upon the amorphous carbon converting it into graphite. The manufacture of paint from artificial graphite has increased considerably, for it is now recognized that a greater purity and uniformity can be obtained than is possible with a natural plant. The most marked increase has been found in the use of graphite for dry batteries. While artificial graphite has been used for some time as a lubricant, it is only within the last year that the problem of producing a lubricant of artificial graphite for high-grade work has been successfully solved. Experiments have also been made with artificial graphite for coating the grains of high explosives; the spontaneous ignition of high explosives is supposed sometimes to be caused by a static charge of electricity on the grains, this causing a spark which detonates the powder; by coating the grains with graphite the formation of the static charge is prevented.

*Calcium Carbide.*—According to a report issued by the German Consul in Havre, and discussed in the London *Elec. Rev.*, February 27th, the calcium carbide industry in France has undergone a considerable change in character since the

Bullier patents were finally proclaimed good in the Paris Court of Appeal. The master patent controlling the manufacture of carbide is the property of the Société des Carbures Métalliques, a Parsian company founded by Bullier, which has a capital of 3,200,000 francs. This concern is practically the owner of 17 carbide factories scattered throughout the Alpine districts, and retails its product through the agency of 50 dealers in different parts of the country, who are compelled to sell at the uniform price of 363 francs per metric ton—an arrangement which has been made in order to encourage the use of the material in districts farthest away from the factories, where it would otherwise be more expensive. The annual production is estimated at 18,000 tons. Forty villages are provided with central acetylene installations. In Havre carbide is retailed at 48 to 51 francs ($9.60 to $10.20) per 100 kilos, in lots from 50 to 500 kilos; and at 45.50 to 48.50 in lots from 500 to 2,000 kilos. The existence of the Bullier patent has prevented the importation of any carbide, but the export trade is growing. Since calcium carbide is not itemized in the official export returns, it is not possible to give the exact figures; but it is probably more than 1,000 metric tons per annum at the present time. The material goes chiefly to Brazil, Argentina, Madagascar, the West Coast of Africa, and to China and Japan. Most of the large steamship companies still dislike taking carbide on board, and leave the carrying trade to the "tramps." Some carbide is sent abroad by sailing vessels. One firm in Havre, however, has made a special point of carbide exportation, sending away 300 tons in 1901, as against 100 in 1900. The price of carbide on board ship at Havre is on the average 350 francs per metric ton, a figure which includes 50 francs per ton, the cost of sending it from the works. The expense of shipping carbide to Brazil is 143 francs per metric ton; so that, including everything, French carbide costs about 550 francs per 1,000 kilos in Brazil, unless very large orders are being taken.

In quite a long article in the *Zeit. f. Calciumcarb. Fab.*, March 20th, Caro discusses critically the process patented by Diester

*Use of Carbide of Silicon.*—An article on the use of carbide of silicon as a substitute for ferro-silicon, in the manufacture of steel. Manufacturers of steel castings were the first to appreciate the value of carbide of silicon, especially in basic open-hearth work. Much of such work, to insure solid castings, calls for a higher silicon content than can be secured from pig iron that comes within basic requirements. If the addition of ferro-silicon is made to the ladle cold, too great chilling results, and it has been customary to melt it first in a separate cupola; while in certain cases it has been the practice to add it directly to the furnace, but this is accompanied by excessive loss of silicon by reason of its rapid action on the basic slag. In an article in the Cleveland *Iron Trade Rev.*, abstracted in the *Eng. and Min. Jour.*, March 28th, the advantages of carbide of silicon are brought out. It contains 62 per cent. of available silicon, and may be added directly to the ladle during the process of tapping, without previous heating. uniform action is secured and complete solution generally takes place by the time the ladle is full. The carbide has also found extended use in making steel for various purposes for which it is first run into ingots and in which the silicon is very much lower than in steel castings, amounting generally to but a trace. Manufacturers of tool steel have found that the freedom of carbide of silicon from phosphorus and sulphur offers great advantages, and it is therefore used in considerable quantities in the open-hearth practice of such manufacturers and to some extent in crucibles. Operators of the acid open-hearth process have used carbide of silicon in cleaning dirty furnace bottoms; when the hearth becomes crusted over, a small quantity of carbide of silicon is sprinkled over it, and on being heated sets up such a scouring action as to reduce the residue to fluid slag which is readily removed from the hearth.

*Electric Steel Furnace.*—An illustrated description of the Kjellin electric furnace for making steel, in use in a Swedish plant, is given by Becker in the *L'Ind. Electrochimique*, March.

*Aluminium.*—J. B. C. Kershaw has another statistical article on the present state of the aluminium industry in the London *Elec. Rev.*, March 20th. The number of works producing aluminium either by the Hall or the Héroult process, is now nine, situated as follows: America, 3; France, 2; Germany, Great Britain, Switzerland and Austria, each 1. The power available for the production of aluminium in these nine works is between 36,000 and 40,000 horse-power, all derived from water. The output of aluminium of all nine works is estimated as 7,340 tons in 1901, and 8,000 tons in 1902. Some information is given on the financial conditions of the various companies and the dividends paid by them.

*Antimony.*—A description and critical discussion of the Izart and Thomas process for the production of antimony from its ores is given in *L'Ind. Electrochimique*, March.

*Electrometallurgy.*—Beadle concludes his serial on electrometallurgical problems in the London *Elec. Rev.*, February 27th, giving brief notes on iron, tin, tungsten, nickel, cobalt, mercury and antimony.

## THEORETICAL AND EXPERIMENTAL.

*Electrolysis of Alkaline Chloride Solutions.*—Messrs. Foerster and Mueller made some very extended experimental researches. The theoretical results concerning the process at the anode are summed up as follows: In the electrolysis of aqueous solutions containing chlorine ions at the anode, two negative chlorine ions discharge to form a chlorine molecule. Besides this, there are formed at the anode hypochlorous acid and hypochlorite, either primarily by a negative Cl ion and a negative OH ion reacting and forming HOCl, while at the same time a negative Cl ion and two negative OH ions react and form a negative ClO ion and a molecule of water, or by a reaction of the primarily formed chlorine gas with negative OH ions at the anode. With an increasing ratio of the concentrations of the OH ions to the Cl ions (*i. e.*, for a more alkaline or for a more dilute chloride solution) the development of negative ClO ions, *i. e.*, the formation of hypochlorites, increases. Besides this electrochemical anodic process, there is also a formation of hypochlorite in the electrolyte by a reaction of the alkalies present there with the chlorine gas formed at the anode. As ClO ions are comparatively more easily discharged than Cl ions, and as the former are destroyed when discharged, it is improbable that the hypochlorite formed at the anode remains to a large degree in the electrolyte; the greater the distance from the anode where it is formed, the greater is the chance that it remains in the electrolyte, yet there are always limitations to the possibility of hypochlorite existing in chloride solutions through which a current flows. Chlorate is formed from ClO ions, which have themselves been previously formed either by an electrochemical anodic process or by a chemical process in the electrolyte; in the former, six negative ClO ions react with three water molecules and form two negative $ClO_3$ ions, plus four negative Cl ions, plus six positive H ions, plus three atoms of O; in the latter process one negative ClO ion, plus two HClO molecules react and give one negative $ClO_3$ ion, plus two positive H ions, plus two negative Cl ions. The anodic electrochemical formation of chlorate is always accompanied by the development of oxygen gas. The anodic electrolytic generation of chlorate requires the presence of hypochlorite which may either have been formed directly by electrochemical action at the anode, or may have been formed chemically in the inside of the electrolyte; in the latter case it takes some time before the hypochlorite reaches the anode and before the formation of chlorate is started. In strong alkaline or neutral, or in very dilute acid chloride solutions, anodic development of oxygen

may be due not only to the discharge of negative ClO ions, but also to the discharge of negative OH ions. The secondary chemical development of chlorate in the interior of the electrolyte takes place without the development of oxygen; this formation of chlorate occurs to a considerable degree when free hypochlorous acid can exist together with hypochlorite in a large part of the electrolyte; that is, when the chloride solution is slightly acid. The account is published in the *Zeit f. Elektrochemie*, February 26th and March 5th.

*Chlorine and Carbon.*—In a previous paper Bolton referred to the direct combination of chlorine with carbon. In the *Zeit. f. Elektrochemie*, March 5th, he now supplements this by showing that if the carbon arc is formed in a chlorine atmosphere in a large space, $C_2Cl_6$ is formed, but if the reaction goes on in a small confined space, $C_4Cl_6$ is formed.

*Aluminium Valves.*—Nodon has continued his experiments with these "valves," as they have been appropriately called, and in the *Comptes Rendus*, February 15th, gives an account of some researches on their internal resistance and their effect upon alternating discharges and telephone currents. He uses an aluminium anode in a concentrated solution of neutral ammonium phosphates, and finds that the capacity of the value may attain as much as 1 farad per square centimeter of aluminium. The thickness of the dielectric forming the condenser is of molecular size, assuming that the dielectric constant is of the order of unity. The capacity has the effect of considerably reducing the e m f of the currents rectified. The apparent specific resistance of the liquid of the valves when open is about 20 to 100 ohm centimeters instead of the 6 ohm centimeters, representing the specific resistance of the electrolyte. No oxide can be seen on the aluminium under the microscope during the passage of a current. The aluminium always presents the aspect of a porous metallic sheet. A telephone current can be measured by rectifying it and using a direct-current galvanometer. Phenomena similar to those obtained with a Wehnelt interrupter may be obtained by putting an aluminium valve in circuit with an alternating current and an induction coil provided with a very light trembler, having a period identical with that of the current rectified. An abstract is given in the London *Elec.*, March 6th.

*Ionizing Power of Organic Liquids.*—Some experiments were recently made by Di Ciommo to study the effect on the resistance of the mixture produced by adding a solid insulator to an insulating liquid. The account is given in the *Phys. Zeit.*, February 15th, and is abstracted briefly in London *Elec.*, March 6th. His mixtures were made by dissolving sulphur in carbon bi-sulphide, or naphthaline in benzol or toluol, and in every case it was found that the addition of the solid non-conductor diminished the resistance of the other. He also found that the diminution increases rapidly at first with the percentage of the solid dissolved, but less rapidly afterwards, giving the appearance that the resistance tends towards an asymptotic limit. Thus, if a quantity of carbon bi-sulphide has a resistance of 17 million megohms, 1.6 per cent. of sulphur dissolved in it reduces the resistance to 8.5 millions, 3.3 per cent. to 4.6 millions, and 16.5 per cent. to 4.1 millions. But the greatest diminution is not such as to affect the order of magnitude of the resistance. The author concludes that no real ionization takes place.

*Radioactivity and Gravitation Energy.*—In Forch and Kucera's two articles Geigel recently tried to prove experimentally that the only energy given out by radioactive substance is equivalent to a loss of gravitation energy. Kucera shows in the *Phys. Zeit.*, March 1st, that Geigel's mathematical calculation is incorrect, while Forch repeated Geigel's experiments under modified conditions in which, if there is really an absorption of gravitation energy, he ought to have obtained 40 or 50 times the effect obtained by Geigel, but his results were negative. Forch's article is published in the same journal.

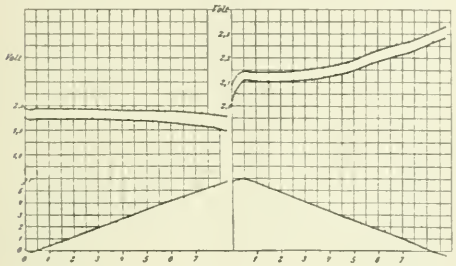
## PRIMARY AND STORAGE BATTERIES.

*Edison Battery.*—Hibbert recently had an opportunity to examine a cell brought to England by H. E. Dick, who is associated with Edison, and gives an account in the London *Elec. Rev.*, March 6th. The cell weighed 18 pounds and had a capacity of 200 watts; it has not yet been in use. Noticeable features are the small distance between the plates, and the compact arrangement in all other respects. In external appearance the containing box, being of nickeled steel, looks much stronger than the wooden or ebonite boxes commonly seen. Some discharge curves are reproduced. The striking feature is the very high percentage of the ampère hour discharge at the higher discharge rates as compared with the normal; the cell is nominally rated at 25 ampères, and then gives about 160 ampère hours at a potential difference of over 1 volt; when the discharge current is raised to eight times this normal value, the ampère hours, with a continuous discharge down to 1 volt, ar practically 125. He thinks that no makes of lead cells would offer a cell giving 75 per cent. of its normal capacity at eight times its normal rate. "During discharge, the density of its liquid is not diminishing, but rather increasing. Hence the ability to call on a greater fraction of the available energy at a higher discharge rate." The manufacturers claim that there is no local action. The ampère hour efficiency, when ten or twelve days intervene between charge and discharge, is only 2 or 3 per cent. less than when the discharges immediately follows the charge. "The general result of an examination of the cell is to remove some antecedent skepticism, and one feels that there is a serious competition to the lead cell not far away. The final decision will appear when the cells are offered to the public and get tried by the infinitely varied rough usage and nescience of the general public. A preliminary to that stage will be reached when an adequate report has been made by outside authority. I understood Mr. Dick to say that this is being arranged for, and till then we must wait with such patience as we can command."

Some abstracts on this battery, taken from American journals, are given by that author in the same journal of February 27th. Editorially that journal in its issue of March 6th says, after examining this cell: "The cell is a model of excellence in mechanical construction; being composed mainly of steel, it afforded the designers a rare opportunity of which they have availed themselves to the full. * * * If all the claims advanced for this cell, or even a part of them, are fulfilled, we may look for more important results from its introduction."

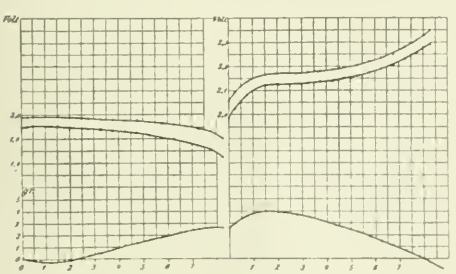
*Lead Accumulator.*—The question of whether a Planté or a pasted positive plate will withstand the action of repeated partial charges and discharges better, has been the subject of much discussion, and is a matter of some importance in batteries used as "buffers," as, for instance, when they are used as equalizers in railway and lighting plants. While actual tests are the best way to settle such a question, yet even in such a test the results could apply only to the specific plates tested, and hardly to types of plates. M. U. Schoop has made some tests which he described in the *Elek. Zeit.*, March 19th, and while they are of interest it hardly follows that the conclusions can be applied to the two types, but only to the specific plates used by him. The gradation from a Planté plate to a Faure plate, may be a very gradual one, after they are well formed, and their difference can hardly be expected to be typical; it is in their process of manufacture that they are typically different. In the tests of Schoop, two accumulators, each having one positive and two negative plates, were compared, which for a one-hour discharge down to the same voltage, had equal capacity and differed only in so far as the single central positive plate in the one cell was a pasted grid plate and in the other a Planté plate, the two negative plates being exactly the same in both cells. The purpose was to study the behavior of pasted and of Planté positive plates in buffer service. The main results are as follows: The determi-

nation of the "true" total surface of a positive or negative accumulator electrode is so very difficult that it may be questioned whether it will ever be possible to determine numerically the true surface which takes part in the electrochemical reaction, its geometrical form being very complicated and changing from moment to moment. The apparent surface of a pasted plate or of a Planté plate, as found from length and breadth, is extremly small as compared with the true surface. It is not quite correct, therefore, to speak of a true current density, and the quotient of the apparent surface to the current is without value for the knowledge of the true current density, as the lines of current are nearer together at prominent points than at points deeper in the plates, and as these lines of current



PLANTE PEROXIDE PLATE.

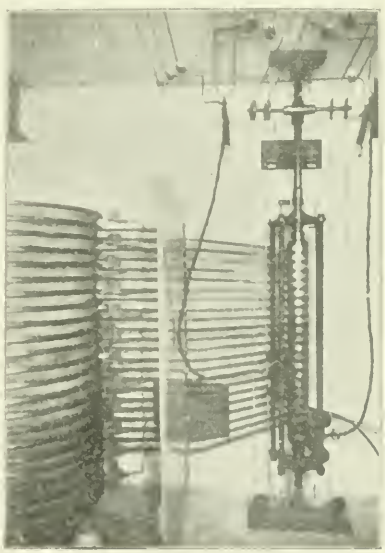
are continually changing their path. The true surface of a so-called "sulphated" positive plate is so small that in a charge with the usual current, such a high density exists that great quantities of ozone are formed. With positive Planté plates the acid diffusion is better than in pasted plates, so that in very quick charges and discharges the active mass is utilized to a greater degree in the former than in the latter. But this advantage of the Planté plates is counterbalanced by the fact that the internal resistance of a Faure accumulator having the same capacity, acid density and density between the plates, is smaller than that of a Planté accumulator; in respect to buffer service the Faure accumulator is therefore thought to be superior to the Planté accumulator. He studied the charge



PASTED PEROXIDE PLATE.

of weight of positive plates during charge and discharge in the following way. Between two negative plates a positive plate was placed, and the latter was suspended on one arm of a balance, so that the change of weight could be studied during the whole time of the tests. He again compared a pasted positive plate in one case with a Planté positive plate in the other case. As the chemical reactions are the same in both cases, the differences in the behavior of both types of plates represents the different conditions of acid diffusion in the plates. One of the adjoining diagrams refers to a pasted peroxide plate, the other to a Planté peroxide plate. The upper curves in both diagrams are the ordinary discharge and charge curves of e m f, while the lower curves give the change of weight in grams. The ordinates represent ampère hours. The acid density was in both cases 1.167 at 19° C., and the current 3 ampères. The two diagrams show very clearly the difference in the conditions of diffusion in both types of plates, the diffusion is much better in the Planté plate than in the pasted plate.

*Preparation of the Active Mass for Lead Storage Batteries.* Leimer begins an article in the *Centralblatt f. Accum.*, March 1st, in which he gives an account of an experimental investigation of the value of various substances which were added to a mixture of water and lead oxides, in order to make the active mass more adherent and durable. Although the water has some hardening effect it is entirely insufficient; and while the sulphuric acid when it afterwards comes into contact with the mass, increases the hardness, there is also the danger of a strong development of gases which may destroy the structure of the active mass. He made experiments with nine different substances: sulphuric acid sp. gr. 1.17 sulphuric acid sp. gr. 1.20, mixed with pure English glycerine, aqueous solutions of phenole, salicylic acid, acetic acid, pyridine, an



SWITCH FOR TRIBELHORN ACCUMULATOR.

alcoholic extract of cobbler's wax, amber dissolved in a mixture of turpentine and carbon bisulphide and finally gelatinous chromium hydrate. The exact composition of these solutions is not given, but it is stated that 10 grams of each of these solutions was mixed with 300 grams of minium. The further preparation of the plates is described. The article is to be concluded and the results will then be published.

*Tribelhorn Storage Battery.* An illustrated description is given in the *Centralblatt f. Accum.*, February 1st, of this accumulator, the characteristic feature of which is that the cone shaped leaden cells are placed one above the other, like in the old Voltaic pile, or in Salomi's lead reduction apparatus, the cells themselves forming the plates. The main advantage is the great saving of space which is claimed to amount to 50 to 75 per cent. The result on of such a battery in a lighting plant is described; it gives 840 or 1,200 ampere hours if discharged in three or ten hours, respectively. It takes about two hours to build up a column. The adjoining diagram shows an end cell switch of very simple construction, connected to such a column. The contact rings, which are insulated from each

other, are mounted on a cylinder, the contact springs being moved on the cylinder (parallel) to its axis and being also adjustable in the direction of the periphery. This switch may be placed at any distance from the battery and is moved from a distant point by a mechanical transmission device; for instance, by a rope acting on the sliding contacts. In order to enable one to place the switch in the immediate neighborhood of the battery, it is made of acid-proof material.

*Sal Ammoniac.*—Rosset in the *Centralblatt f. Accum.*, February 1st, gives a description of simple practical methods for rapid determinations of the purity of commercial sal-ammoniac which is to be used for galvanic cells. For this purpose it should be quite pure and should not contain too large quantities of sodium chloride or ammonium sulphate. The two methods which he found most practical are to determine the specific gravity of the solution at a given concentration and the temperature decrease due to the solution in water. The specific gravity method is most sensitive for strong solutions, and the temperature-decrease method for dilute solutions. He prepares a saturated solution with a large excess of the salt and determines the specific gravity at 15° C. If it is greater than 1.0766 (10.25° B), the sal ammoniac is not pure. The absence of sulphates, and especially of ammonium sulphate, is shown when barium chloride or acetate does not give a precipitate. He then makes a solution of the concentration used, and determines the temperature decrease; as this takes place after thirty or forty-five seconds, it is necessary to work quickly; the water and the salt must of course have the same temperatures at the start. If 25, 50, or 75 grains of sal-ammoniac are dissolved in 250 cc water, pure sal-ammoniac gives a temperature decrease of 6, 11.5 and 15 C., respectively; if the sal-ammoniac contains 10 per cent. sodium chloride, the temperature decrease is 5.5, 10.75, and 14.25° respectively.

*Galvanic Cells.*—An article by Mugdan is begun in the *Chem. Zeit.*, March 15th, in which he intends to discuss the possibility of commercial carbon cells. In the present installment he deals with the principles of the galvanic cells in general; this is first briefly discussed from the point of view of the electrolytic dissociation theory and afterwards from the basis of the principles of thermodynamics. In the light of the second law of thermodynamics he considers the galvanic cell to be the most simple ideal machine for obtaining the maximum possible mechanical work from a given process.

*Standard Cells.*—Jaeger contributes another article on some recent researches, especially in connection with the Weston cadmium standard cell. It had been found that some cadmium cells showed irregularities when used near 0° C., but this was found to be due to the use of too strong an amalgam, containing 14.3 parts (by weight) of cadmium per 100 parts of amalgam (*i. e.*, 1 cadmium per 6 mercury); such an amalgam undergoes a change at 0°. If a slightly more dilute amalgam is used, there are no irregularities whatever. In the Reichsanstalt, about 80 cadmium cells, partly with 12 per cent. and partly with 13 per cent. cadmium amalgam were tested, and although they were kept for a week at zero temperature, no irregularities were found. The supposition that the irregularity found in the cells with the 14.3 per cent. amalgam were due to a change of the electrolyte cadmium sulphate, has been proved to be wrong. There is no change whatever in the cadmium sulphate, and if a 12 to 13 per cent. amalgam is used, the cadmium cell is absolutely reliable and very convenient on account of its small temperature coefficient. The article is published in the *Centralblatt f. Accum.*, March 1st.

*Lighting of Railway Cars.*—Goetze begins an article in the *Centralblatt f. Accum.*, March 15th, in which he discusses the various systems of electric lighting of railway cars.

## MISCELLANEOUS.

*Steam Power versus Hydraulic Power.* In the *Elek. Zeit.*, February 19th, Hecker discusses the prospects of a proposition made in a special case in practice, to erect a hydraulic installation, which if all the available water is utilized, would give a power of 600 horse-power. The cost of the hydraulic plant alone, without the electric plant, is estimated at about $375,000, while that of a steam plant of the same capacity is estimated at $100,000. But as the cost of operation is higher for the steam plant than for the hydraulic one, the question arises under which condition one of them is financially more economical than the other. This is the question which the author discusses under certain suppositions concerning interest, etc., and reaches the conclusion that the hydraulic plant is more economical than the steam plant only when the load factor is more than 60 per cent. during the total time.

*Mineral Spring Waters and Physical Chemistry.*—Referring to some recent critical papers, Juettner discusses the abuse of the electrolytic dissociation theory and of the teachings of physical chemistry, by physicians in charge of mineral springs. For instance, one physician claims that it is only in natural mineral waters that the salts are dissociated into ions and that they are therefore healthful, while in artificial salt solutions he claims that the ions are not ionized; such absurd claims are then reprinted in many prospectuses. A claim made by another physician is that the water from a certain mineral spring is very healthful because its electrical conductivity is 6.1 times that of pure distilled water; but he does not say that ordinary water has a still better conductivity. The electric charges of the ions are said to be the property which makes them healthful. The author analyses critically several tests of mineral waters made by methods used in physical chemistry. The ordinary chemical analysis is quite sufficient and the application of the teachings of physical chemistry is a "luxury." There is great danger that these physicians' abuse of the teachings of physical chemistry will bring it into disrepute. The article is contained in the *Zeit. f. Elektrochemie*, February 26th.

*Copper Cadmium Alloys.*—Denso tried to determine which compound is crystallized out from molten copper cadmium alloys having an excess of cadmium. Alloys of various compositions were tested, and from all of them the same compound $CuCd_3$ was obtained. For further details see *Zeit. f. Elektrochemie*, February 12th.

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The Electric Club, Pittsburg, Pa.—The first annual report of the Electric Club, Pittsburg, Pa., is issued in the form of a very neat illustrated booklet under date of March 19, 1903, the anniversary of the Club's organization. This pamphlet, of artistic design, gives the constitution and membership of the Club, the scope, plans and personnel of the various committees, and an outline of the work accomplished and proposed. A feature of this work which has proven very valuable is the formation of classes for the study of technical subjects under the instruction of various engineers of the Westinghouse Electric and Mfg. Co. These classes, or "sections," constitute "self-exciting" engineering societies within the parent body, each section pursuing a separate and definite line of study. As a further aid, there is a well-equipped technical library, including the various electrical and mechanical magazines. The social side of life is directed by the committee in charge, of which not the least is that known as the Ladies' Committee, an ever-to-be-desired element in any club. The Club has proved to be a decided success.

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*Geological Course.*—Harvard University offers a summer course of five weeks in geological field work in the Rocky Mountains, beginning about July 1st. Prof. Charles H. White, of Harvard University, will have charge of the course. The field selected includes the higher groups of mountains in Southwestern Colorado.

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl.

### Electric Furnaces and Furnace Products.

*Electric Furnace.* P. L. T. Heroult, La Praz, France. Assignor to Société Electro Metallurgical Française, Froges, Isère, France. Patent 721,703, March 3, 1903. Application filed October 11, 1900.

This furnace was designed by Heroult for the purpose of obtaining metals such as chromium, manganese and iron, and generally substances which tend to combine with carbon. In order to avoid as much as possible the introduction of carbon from the electrodes into the product, two separate arcs in series are employed, which play through an insulating layer of slag between the fused conducting material on the one hand and the two electrodes on the other hand. Fig. 1 shows the furnace in cross section. It consists of a crucible *a* of a suitable

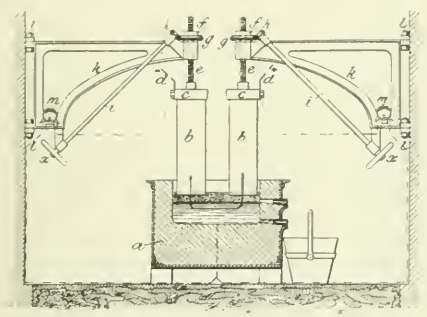


FIG. 1—HEROULT'S ELECTRIC FURNACE.

refractory material, inclosed in an iron casing and provided with two tap holes, the lower one for the metal, and the upper one for the slag. The two electrodes are supported by cantilever frames *k, k* and can be raised or lowered by hand wheels *x, x* and suitable gearing. In order to insure the distinct formation of the two arcs, a shunt circuit is arranged between each electrode and the fused material, with voltmeters *m, m*, the indications of which serve to constantly verify and regulate the position of the electrodes and to indicate, whether the furnace is working properly or not. Either continuous or alternating currents can be used, and polyphase currents could be employed by providing more than two electrodes with the means described of regulating their positions. It is stated that the arrangement is applicable not only to the reduction of ores, but also to the decarbonization of substances treated with oxidizing slags or with an air blast, such as steel or iron. The slag in this apparatus forms the resisting medium, in which the heat is produced. The furnace is evidently an improvement on the one described in Electrochemical Industry, Vol. I, page 63.

*Electric Furnace.* Albert A. Shade, Chicago, Ill. Patent 722,411, March 10, 1903. Application filed May 15, 1902.

This furnace shows a more simplified construction than the one described by the same inventor in patent No. 713,923, of November 18, 1902 (Electrochemical Industry, Vol. I, page 187). The zigzag passages of the latter have given place to a single inclined passage in this one, with a refractory wall of fire brick or like material and a transversely curved bottom. Three pairs of carbon electrodes extend into the lower end of this passage. Magnets are provided again as in the former patent, and arranged below the arcs in such a manner, as to deflect them onto the material to be treated. Metallic shield plates are employed in order to prevent the lines of force of adjacent magnets to interfere with each other. Peep holes are arranged opposite to the arcs. In order to feed the electrodes into the furnace, as they are consumed, they are provided on one side with spirally arranged grooves, forming partial screw threads, which are engaged by a threaded rotating shaft, which is actuated by a hand wheel. The masonry construction of the furnace is inclosed with metallic plates, and space is left between the masonry and the plates, to be filled with asbestos or other insulating material. The material to be treated is fed into a hopper and passes into a chamber where provision is made to heat it by the waste gases from the furnace. It then falls on the inclined passage, where provision is made for still further heating it before it comes under the influence of the arcs. For this purpose three pairs of gas burners are arranged between the charging end of the furnace and the first pair of electrodes, directed downwards in order to play on the bottom of the inclined passage. The material is in this manner thoroughly dried and considerably raised in temperature, and the action of the arcs is facilitated. It then passes successively through the three arcs and is gradually fused and the number of the arcs and the length of the inclined passage are so arranged, that the material, when it reaches the discharge spout, is entirely fused. It is drawn into a suitable receptacle and subjected to further treatment. It is stated that the furnace may be used for smelting or fusing all kinds of material requiring an intense heat for reduction, and is especially adaptable for reducing silica or silica compounds in the process of making glass or like vitreous materials. When the furnace is used for glass making, it is evidently intended to have the liquation of the glass take place in another furnace. A contamination of the melt by carbon particles falling from the electrodes would probably also be likely to take place.

*Method of Producing Compounds Containing Silicon, Oxygen and Carbon.* E. G. Acheson, Niagara Falls. Patent 722,702, March 17, 1903. Application filed November 20, 1902.

*Refractory Material.* E. G. Acheson, Niagara Falls. Patent 722,703, March 17, 1903. Application filed November 20, 1902.

These two specifications protect, respectively, a method of producing compounds containing silicon, oxygen and carbon, and the resulting products. Mr. Acheson discloses methods of treating carbonaceous and siliceous material, whereby silicon oxygen carbon compounds are produced, which he designates by the general term "siloxicon." These compounds are said to be very refractory under high temperatures, insoluble in iron, inert towards acid or basic slags, and readily striped into any desired form. Instead of mixing silica with a small excess of carbon, over that required to reduce it, and to form carborundum, the amount of carbon in the mixture for the production of the compounds under consideration is insufficient for the reduction of all of the silica. The reduction is, therefore, incomplete, and a certain amount of oxygen is retained in chemical combination with the silicon, and compounds containing silicon, oxygen and carbon are formed. Thus a compound corresponding approximately to the compounds $Si_2C_2O$ and $Si_3C_3O$ and analogous compounds have been produced. In order to manufacture these compounds satisfactorily, it is necessary to keep the temperature of the electric furnace below that required for the formation of carborundum, as decomposition takes place at or about that temperature, possibly in accordance with the equation $Si\text{-}C\text{-}O = SiC + Si + CO$. The silicon and carbon monoxide escape

from the furnace as vapor and gas, while the carbide of silicon remains behind as crystals of carborundum. In order to carry out the method, 33⅓ per cent. of powdered carbon, and 66⅔ per cent. of powdered silica are mixed thoroughly together. When the mixed materials are fine-grained, a little saw-dust is added to increase the porosity, and the proportions of the above mixture are modified in view of the silica and carbon content of the saw-dust. The silica content of the carbon is also considered in the preparation of the charge. The mixture is then charged into the electric furnace and upon subjection for a suitable period to a temperature below that required for the production of carborundum, the product is found to consist of the above described chemical compound containing silicon, oxygen and carbon. In a concrete case the furnace was 56 inches long, 20 inches wide and 14 inches deep, and contained two cores of graular coke, 3 inches in diameter and 48 inches long. It was filled with the described mixture, and the current was started with 85 volts and 500 ampères. The volts remained practically constant, while the ampères soon increased to 600, after which they remained practically constant to the end of the operation, which lasted nine hours. After cooling and opening the furnace, all of that part of the charge occupying the space between and for a certain distance around the cores was found to be converted into loose granular or pulverulent amorphous material, which was gray-green, when cold, and light-yellow, when heated to 300° F. or over. An analysis of the material gave the following composition by weight: Si = 57.7; Ca = 25.9; Fe = 2.1; Al = 0.4; Ca = trace, Mg = trace, O (by difference) = 13.9.

Crucibles made of "siloxicon" are found to be superior to the crucibles of clay or graphite and clay, as they are not acted upon by molten metal or slag, nor are they worn away laterally by the action of the fuel or furnace gases. It is considered preferable to utilize the self-binding properties of "siloxicon" in its various applications to articles or linings. A suitable binding agent, such as tar, asphaltum, molasses, etc., may, however, be mixed with the material and the resultant mass molded into the desired forms, which may then be burned or may be used without burning. When the "siloxicon" is to be used as a furnace lining, it is sometimes preferable to prepare the mixture and tap or ram it into place, where it later receives its final heating. "Siloxicon," as will be seen from the above description, represents another addition to the list of valuable products, which Mr. Acheson has placed at the disposal of the metallurgist, through his persistent and indefatigable work in extending and perfecting the use of the electric furnace.

*Method of Subdividing Blocks or Ingots.* Joseph Scales, of Niagara Falls, N. Y., assignor to Union Carbide Co. Patent 722,750, March 17, 1903. Application filed January 13, 1903.

This invention is an amplification of the inventor's former patent for a method of subdividing blocks or ingots of calcium carbide, patent No. 719,882 of February 3, 1903 (ELECTROCHEMICAL INDUSTRY, Vol. I, page 251). In that patent a method was described for detaching large pieces of carbide from the ingots produced in calcium carbide furnaces, especially of the Horry type, as used by the Union Carbide Co. at Niagara Falls. The method consisted in drilling one or more holes into the block of calcium carbide, while it is still in a highly-heated state, and at the same time injecting water or steam into the cavity, preferably through the drill, thus effecting a local disintegration of the carbide. Another method consisted in effecting such local disintegration by a jet of steam or water alone, without the use of the drill or any other mechanical appliance. The present specification amplifies the claim, by broadly claiming the use of reagents in general, on any blocks or ingots. The inventor says: "My method may be applied to other materials than calcium carbide, and other reagents than water, air or steam may be employed, the particular reagent being chosen with reference to the character of the material, upon which it is desired to operate. It is essential only that the reagent be capable of acting upon the block or ingot in a heated state, to cause a local solution or disintegration, which will assist its subdivision."

APPARATUS AND PROCESSES FOR THE ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

*Secondary Electrode for Electrolytic Apparatus.* Paul Imhoff, Liverpool, England, assignor to United Alkali Co., of Liverpool. Patent 722,583, March 10, 1903. Application filed December 17, 1902.

The object of this invention is to provide a secondary, or as it is usually called, a bi-polar electrode, for use in the manufacture of chlorates. The inventor wants to do away with the use of the expensive all-platinum electrodes, as used at present, and, therefore, constructs his electrodes out of an anode built up of platinum wire and a cathode of a cheaper conducting material in the form of wires, rods, plates, bars, strips or gauze. Both anode and cathode are built upon opposite sides of a non-conducting supporting plate or body of slate, glass, stone or other suitable material. The necessary connections between the anode and cathode are made by bringing the ends of the platinum wires or strips of the anode around the edges of, or through holes in the supporting plate, and welding wrapping or otherwise fastening them to the cathode material. Fig. 2 represents a cross-section of the construction, showing the anode *a*, consisting of a platinum wire. *c* is the supporting plate of non-conducting material, which separates the anode and cathode material, and *b* is the cathode in the form of a rod. Distance pieces or strips *d*, keep the anode and cathode material from contact with the plate *c*. The platinum wires of the anode are passed through holes in the supporting plate. Very good results are said to be obtained with a cathode of iron or of carbon.

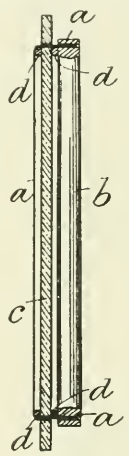


FIG. 2.—BIPOLAR ELECTRODE.

*Manufacture of Titanous Chloride.* Howard Spence, Manchester, England. Patent 723,217, March 17, 1903. Application filed August 15, 1902.

The inventor claims to have discovered a new crystalline titanium chloride compound, produced by electrolysis, having chemical and physical characteristics different from the compound known up to now and described by Glatzel already in 1832, under the formula $Ti_2Cl_6 + 8\ H_2O$. The new compound is stated to possess important qualities for commercial use as a reducing agent in various manufactures, its reducing power being much greater than that of the existing chemical reducing agents, such as stannous chloride. The method of procedure consists in subjecting a solution of titantic chloride, $TiCl_4$, obtained by dissolving orthotitanic acid in hydrochloric acid, to electrolysis. The solution may suitably contain about 25 per cent. of $TiCl_4$. The cell, in which the electrolysis is carried out, is divided by a porous diaphragm into two compartments, and contains a cathode of lead and an anode of carbon. The solution of titanic chloride is introduced into the cathode compartment, and a dilute acid solution, *f. e.*, dilute hydrochloric acid, is introduced into the anode compartment. Satisfactory results are said to be obtained with a current density of about 200 ampères per square meter, at a tension of from three to four volts. On closing the circuit the $TiCl_4$ solution is readily and rapidly reduced to $Ti_2Cl_6$, the liquor being kept at the ordinary or at a slightly elevated temperature. More than 90 per cent. of the $TiCl_4$ is stated to be converted into $Ti_2Cl_6$. The chlorine gas given off at the anode may be utilized as usual. The solution of $Ti_2Cl_6$ thus produced is then concentrated, by preference at a lower temperature and under

required pressure. Unlike Glatzel's solution, which decomposes during evaporation, this solution is said to remain quite stable, and any slight decomposition, occurring at the commencement of the concentration, is due to the decomposition of some $TiCl_4$, which has escaped reduction during electrolysis. The concentration of the liquor continued until a specific gravity of about 1.5 at 650 to 70° C. is obtained, yields on cooling an abundant crop of crystals of the new compound. This product is of a lilac shade of color, showing more violet when damp, while Glatzel's compound was green. The new compound forms a very stable body, soluble with extreme readiness in water to a clear solution. No analyses are given by the inventor to prove that his compound is really new. $Ti_2Cl_6$ has been described as a violent compound by O. v. d. Pfordten (Liebig's Annalen, 237, 217), but unlike the compound described above was hygroscopic and dissolved on heating to a violet solution.

*Reducing Indigo.* R. Mueller and Otto Schwab, Hoechst-on-the-Main, Germany, assignors to Farbwerke, vormals Meister, Lucius & Bruning. Patent 723,007, March 17, 1903. Application filed July 29, 1902.

The inventors have found that the reduction of indigo may be practically carried out by means of the electric current and in presence of warm sulphite solutions. In this process the sulphite or the hydrosulphite resulting therefrom, serves as a carrier of the reducing action of the electric current, that is to say, the electric current does not directly reduce the indigo, but it reduces the sulphite to hydrosulphite and the latter first reduces the indigo. The process may be conducted in such a manner as to directly obtain a solid indigo-white product, pretty stable even when exposed to the air. Care has to be taken that the liquid does not become too alkaline during the electrolysis, otherwise an indigo-white solution will be the result. The best mode of operation is stated to be as follows: 300 grams of indigo paste of 25 per cent., with 415 cubic centimeters of a solution of sodium sulphate of about 30 per cent. strength, 415 cc of a sodium sulphite solution, containing about 10 per cent. of $SO_2$ and 55 cc of a sodium-bi-sulphite solution, containing about 40 per cent. of $NaHSO_3$. The electrolysis takes place in a vessel without diaphragm, with stirring, at a temperature of about 80° C. The electrodes are of lead and the current density is about 3 to 5 ampères per square decimeter. The density of current and the voltage may vary between wide limits. After about 2.4 ampère hours the indigo is reduced, and the indigo-white resulting may be filtered and obtained free from the above-mentioned salts by washing it with hot water.

*Electroplating Apparatus.* Joseph Walters, Sumter, N. C. Patent 721,402, February 24, 1903. Application filed March 22, 1902.

This invention relates to an improvement in electroplating apparatus, and more particularly to means for cleaning and buffing, as well as plating, the object being to construct a simple, portable apparatus, so constructed that it can be used interchangeably for preparing articles to be plated and then for plating them. Fig. 3 shows the construction of the apparatus. A represents a plating tank, filled with an electroplating solution, in which suitable anode plates 1 are suspended and connected to a source of current. A frame 2, resting on the top of the tank, supports two uprights 3, adjustably fastened by screws 4. The lower ends of the uprights are provided with bearings 6a, for supporting a rod or shaft 6 of metal, preferably copper, which serves as the cathode of the apparatus. This shaft is held stationary, by bending it upwards to form an arm 7, fastened to one end of the frame by a fastening device 8. A binding post 9 on this arm is connected with the negative terminal of the source of current. A drum 10, of non-metallic material (preferably wood), is mounted to revolve on shaft 6, and this drum is provided with numerous perforations, in order to permit the entrance of the solution in which it is immersed. The shaft 6 is provided with a series of conducting arms 11 within the drum, which extend to points in proximity to the drum. A shaft 13 is mounted in the uprights, bearing a pulley 14, which by means of a driving belt 15 transmits motion to the drum. The inventor states that by this apparatus the cleaning and preparing of the articles to be plated can be effected without scratching them. The articles can be placed in the perforated drum, the apparatus

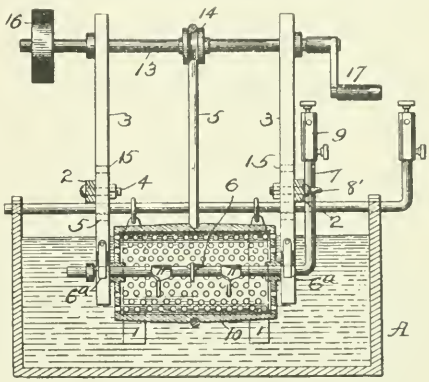



FIG. 3.—ELECTROPLATING APPARATUS.

set over a lye kettle, and then by turning the crank 17, the articles will be made to roll over each other and become perfectly clean. As the rotating of the objects under water or solution prevents them from becoming scratched, the apparatus can then be removed to a washing tank, and the articles can be washed in the same manner. After the articles have been perfectly washed, the apparatus, with the articles still contained in the drum, is placed in position on the plating tank. By applying power to the drum, the articles will then be made to rotate in the plating solution, where they will not only become perfectly plated, but by rubbing against each other will be burnished or polished to such an extent, as to avoid the necessity of much of the subsequent finishing, which has been necessary heretofore.

*Silver Plating or Gilding Process.* Joseph A. Schiele, Brussels, Belgium. Patent No. 722,148, March 3, 1903. Application filed September 1, 1902.

The invention aims at avoiding the use of copper as a preliminary deposit, preparatory to silver plating or gilding surgical instruments, household utensils, covers, etc., in order to escape the troubles caused by the copper when the plating has worn off in spots. For this reason a preparatory bath is used of a special composition, by which it is claimed that an absolutely adherent and resistent coating can be obtained, which allows silver plating or gilding to be applied in the usual manner. The silver plating is claimed to be more adhesive, more durable and finer than that done in the usual manner. The preparatory bath consists of an ordinary tinning bath with the addition of a solution of salts of aluminium and magnesium. If a bath of 10 liters is required, 500 grams of pyrophosphate of sodium are dissolved in 9 liters of distilled water. Then 100 grams of crystallized protochloride of tin are placed in a cloth or sieve and immersed in the solution until complete solution has taken place. The preparation thus formed constitutes the well-known bath, in which objects of iron, etc., are tinned, but such a coating is said not to be suitable for a silver plating or gilding coating, which would peel off on the least rubbing. Therefore, to this first bath is added a solution of 50 grams of nitrate of aluminium and 50 grams of nitrate of magnesium in 1 liter of distilled water. This mixture constitutes the electrolyte, thin plates of tin and aluminium are

used as the anode, while the cathode is formed by the objects to be plated. The metallic objects, previously well polished and cleaned, are put into the bath and are claimed to become coated with a layer, consisting of an alloy of tin, aluminium and magnesium, after which they are thoroughly rinsed and put into a silver plating bath. It is claimed that by the addition of the aluminium and magnesium salts the coating of tin acquires durability and adhesive power, especially to iron. Not only iron and steel, but other metals, which up to the present could not be silver plated or gilded, without the use of the copper bath, can be treated in the manner described. It is also stated that as the deposit is whiter than in ordinary silver plating, the troublesome burnishing operation by means of agate or blood stone can be dispensed with, the finishing being effected with the aid of a polishing cloth and paste or powder.

### Storage Batteries.

*Reversible Galvanic Battery.* Thomas A. Edison, Llewellyn Park, N. J. Patent 721,862, March 3, 1903. Application filed November 28, 1902.

In this specification Mr. Edison describes another modification of his alkaline storage battery, with an electrode composed of oxide of cobalt, preferably mixed with metallic mercury or with metallic mercury and copper or silver, whereby a great proportion of the cobalt oxide is kept in electrical contact with the electrode. The preparation of the electrode he describes as follows: "Dried oxalate of cobalt is first produced in any suitable way and is ignited and kept at a low temperature in the air, until it has been wholly decomposed to form the anhydrous oxide of cobalt. This oxide is then mixed with, preferably, about 15 per cent. of precipitated oxide of mercury, if an electrode is to be obtained, composed of cobalt and mercury, or, if desired, it may be mixed, preferably, with about 25 per cent. of finely-divided metallic copper and 6 per cent. of precipitated oxide of mercury, if the resulting electrode is to be formed of cobalt and a combination of copper and mercury. These proportions may, of course, be varied, but those indicated give good results. I find, in fact, that by increasing the proportion of mercury, or of mercury and copper, a larger proportion of the cobalt is rendered active; but the increase in efficiency is secured at a sacrifice of lightness and economy. Silver may also be employed in place of the copper; but it possesses the objection of being too expensive at the present time for economical use. The mixture of oxide of cobalt and oxide of mercury, or of oxide of cobalt, metallic copper and oxide of mercury is then mixed thoroughly, formed into briquettes and utilized in any desired manner, preferably, by being supported in perforated nickel-plated pockets or receptacles, which in turn are crimped in position within plates or grids. An electrode, containing a mixture of cobalt and mercury, or of cobalt, mercury and copper or silver, is preferably employed in a solution of say, 20 per cent. of potassium hydroxide in water, opposed to a depolarizing element containing nickel hydroxide as the active material, mixed with foliated or flake graphite. When such a combination has been charged and recharged several times, its average voltage is about 1.10 volts. When such a combination is in a fully charged condition, the nickel hydroxide is raised to a very high state of oxidation, and the cobalt is reduced, so far as its active particles are concerned, to the metallic state. On discharging, the nickel hydroxide reverts to a lower condition of oxidation, while the metallic cobalt is oxidized. Owing to the relative ease, as compared to cobalt, with which mercury and copper reduce, the added mercury or copper or silver, if used, will be reduced to the metallic state when the battery is first charged, so as to procure good electrical contact between the active cobalt particles. Since the cobalt on discharge oxidizes much more readily than either mercury, copper or silver, the latter materials remain in metallic form, and their presence serves wholly to assist the electrical conduction between the particles of the active material." Mercury, copper or silver are added by preference to the oxide of cobalt for the purpose of maintaining contact between the active materials, but any insoluble conducting material, preferably in flake form, such as flake graphite, can be used for this purpose.

*Electrode for Reversible Galvanic Batteries.* Herbert Cottrell, Newark, N. J. Patent 722,947, March 17, 1903. Application filed September 13, 1902.

The invention consists in the construction of the electrode, which is made either wholly or in part of carbonized cellulose, and in which this carbonized material serves both as the absorbent for the materials to be rendered active in the battery and its casing. The plates are preferably formed of carbonized cotton textile fabric, arranged in several layers in conductive contact with each other. They may be made of a comparatively finely-woven cotton fabric and should be carbonized to a soft degree only. They may be permeated with metallic salts in solution, such as lead salts, or they may be coated with a material to be rendered active in the battery, *f i* lead or lead oxide. These plates are then inclosed between exterior plates made preferably of coarser fabric of a more open weave and carbonized to a higher degree, and usually treated with liquid hydrocarbon and again carbonized, to give them greater strength and rigidity. The whole group is then subjected to sufficient pressure to insure uniformity of thickness, and the edges are joined by an electrically conductive cement, so as to form a homogeneous plate. The accompanying Fig. 3, shows the plate, where *a* represent the interior layers of soft fabric, *b* the outer more rigid plates, *c* the metallic frame, and *d* the joining of the edges by a suitable cement. It is claimed that this structure favors the absorption and the evolving of gases, so that a rapid charge may be made without disintegration and a rapid discharge without detriment.

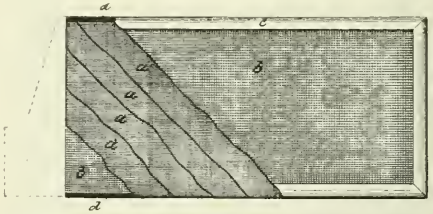



FIG. 4.—STORAGE BATTERY PLATE.

*Frame for Battery-Electrodes.* Herbert Cottrell, Newark, N. J. Patent 722,940, March 17, 1903. Application filed September 13, 1902.

The object of the invention is to provide a frame for holding battery plates, probably of such character as described in the preceding patent. The claim reads: "A holder for electrode plates for reversible galvanic cells, comprising a frame of sheet material, doubled, to clip the electrode plates in its fold; and having a top extension, perforated to receive a bolt, whereby the frame may be clamped and from which it may be suspended."

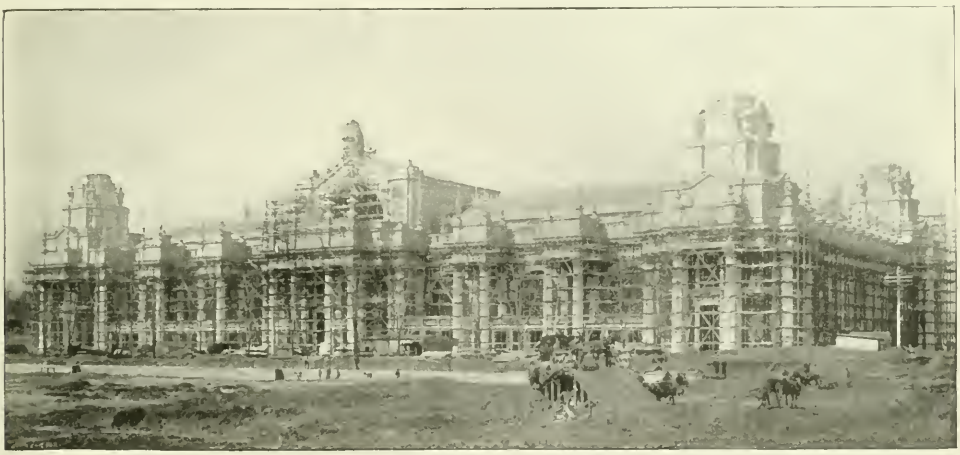
### Galvanic Elements.

*Galvanic Battery.* M. M. Bair, Levallois-Perret, France. Patent 722,652, March 17, 1903. Application filed March 31, 1901.

This invention relates to galvanic cells or batteries of the kind that are hermetically sealed and intended for use in motor vehicles, and is particularly applicable to cells of the Leclanché type. The cell is provided with a detachable lid, to which the electrodes and the porous chamber may or may not be attached. The lid is so arranged that it can be secured to the outer vessel or to the outer vessel and porous chamber by means of resilient clamping frames, so as to maintain the lid hermetically in place and yet permit of its ready detachment.

## THE DEPARTMENT OF ELECTRICITY OF THE ST. LOUIS EXPOSITION.

The Electricity Building of the Universal Exposition of 1904 is rapidly nearing completion. The accompanying views of this building are reproductions of photographs taken only in the last days of March and illustrate the marked progress which has been made within the last few months. By April 30th of this year—the date on which elaborate dedication exercises are to be held in St. Louis—the scaffolding will all have been removed and the building will stand complete, all but the sculptural decoration in the way of groups of statuary. The latter are to be very elaborate. A large group typifying electricity will surmount each of the corner pedestals, and smaller groups typifying the attributes of electricity, heat, light, power and speed, will be placed above the twin columns along the eastern facade, which borders on the Grand Basin and the Cascades. Statues of Franklin, Henry, Volta, Ohm, Ampère and Faraday will be placed opposite the principal entrances of the building and along the eastern front, each bearing an appropriate inscription.



ELECTRICITY BUILDING, ST. LOUIS EXPOSITION.

The Department of Electricity, with the co-operation of the Department of Mines and Metallurgy, is preparing for a most extensive exhibit of electrochemical and electrometallurgical progresses. For those exhibits, which from their nature do not admit of being placed within the exhibit palaces, there will be provided a special building having an area of 60,000 square feet, in which it will be possible to make any and all experimental demonstrations.

In industrial electrochemistry and electrometallurgy America stands already in the front rank; and to the European visitors the electrochemical exhibits will not be the least interesting.

The attitude of the Exposition authorities towards the electrochemical industries is certainly a most friendly and helpful one, and we trust that advantage of this will be taken by all in promoting a fine, historical, experimental and commercial exhibit in electrochemistry. We sincerely hope that all workers in the electrochemical field will give an united and hearty support to the Committee of the American Electrochemical Society, recently appointed to encourage and stimulate an interest in the electrochemical group of the Exposition.

## CURRENT NOTES.

Biography of C. P. Steinmetz.—To the March issue of *Success*, Mr. Herbert Wallace contributes a very interesting and in some parts extremely amusing story of the early life of Mr. Charles Proteus Steinmetz, the famous electrician of the General Electrical Co., who, in a discussion of the (British) Institution of Electrical Engineers, was once called the "Maxwell of alternating current engineering"—a title which he fully deserves. The biographical sketch gives Mr. Steinmetz's life to the time when he came to the United States and found a position first as draughtsman with the Eickemeyer Co. and afterwards as the engineer in charge of the experimental work of the same company. Here the story stops, probably because the later life work of Mr. Steinmetz—beginning with his celebrated hysteresis researches in Eickemeyer's laboratory—is well known to every electrical engineer. The greatest part of the article is given in Mr. Steinmetz's own words, so that the sketch may be called an autobiography. It may be of special interest to our readers to learn that Mr. Steinmetz is greatly interested in chemistry, and at one time of his life intended to make his living as a chemist.

C. P. Steinmetz was born April 9, 1865, in Breslau, Germany. For twelve years he attended the gymnasium and afterwards for five years the university of the same city. As a boy at home, he had a small chemical laboratory, and used to spend a good deal of time in it. But his main interest centred in mathematics. "I want to say that absolutely all the success I have had has been due to my thorough study of mathematics.

"I went to the university to study mathematics and astronomy. It was somewhat before the time of electrical engineering. The arc and incandescent lamps did not exist, except, perhaps, as curiosities. Then I became interested in physical science, and studied physics, and, later on, natural history. It was some time before I began the study of electrical engineering, and then, strangely enough, it was chiefly because of my friendship for a fellow student who was pursuing that subject. When I commenced, I had no thought of making any practical application of it; I merely wanted to know something about the subject."

Mr. Steinmetz was twenty years old when he met his electrical engineer friend. It was through him, also, that he became connected with the Social Democratic party; and this connection was finally the reason why he left Germany. He had become the editor of a Socialist paper (a position for which he never received a cent), but, to divert the police, his friends got a Polish fish vendor to be recorded as the responsible editor. "Finally, the police confiscated the Socialist paper. They arrested the supposed editor, the Polish herring man, and wrote out a statement for him to sign, but he could

not write his own name. He and several others, among them my electrical engineer friend, were thrown into prison, and the Government officials were sure they had all the leaders, and that the movement had been effectually broken up."

The story how a regular secret correspondence was carried on between the prison and the outside world by means of letters written by simple chemicals, and later developed by chemical means, is very amusing. Later, however, the police began to become suspicious and were about to arrest Steinmetz. He preferred to leave Germany and went to Zurich, Switzerland.

"Before I left Germany, I had intended to become a chemist. Because I was a Socialist, I could not bring myself to accept a Government position, and I could not have earned a living at mathematics except in a Government position. Electrical engineering really did not then amount to anything in Germany, and chemistry seemed the only field in which I could make a good living. When I reached Switzerland, however, I decided to take up mechanical engineering. I knew much about a good many things, but nothing by which I could make a living. Obviously, my political career was ended.

"I had arrived in Zurich in June, 1888. I studied privately during the summer, and in the fall entered the Polytechnic School with an elective course, made up of mechanical engineering, turbine, steam engine, bridge construction, designing, etc. A friend and I lived together, and cooked our own meals. The following year, my friend's guardian directed him to go to America, and I decided to go with him.

"We sailed in the steerage on a French liner, paying 75 francs from Zurich to New York. I have crossed the ocean since, in the first cabin, but I have not had so pleasant a voyage since, as was that one in the steerage."

He succeeded in getting a position as draughtsman with the Eickemeyer Co. in Yonkers, at a salary of $12 a week. "My friend also succeeded in getting a place, and we took up our former housekeeping plan together, in a room in New York City. I had to get up very early, prepare breakfast, and go to Yonkers. Our plan worked very well, with but one drawback. We could never agree as to who should wash the dishes." (There is an unauthorized story, not mentioned in the article, stating that they would wait till they had company and then would have their friends do the dishwashing.) "We were both good cooks, and managed to live cheaply and well but, after a year of this life, my friend had his fiancee come from Germany, and they were married. Then I moved to Yonkers, to be nearer my work."

His knowledge of chemistry was of advantage to him, to be graduated from draughting. "It was a very simple thing. One day Mr. Eichemeyer happened to come into the room where we were working, and he was in a great rage because he had stained his fingers with aniline ink and could not get it off. I told him to use a certain acid, diluted, and the ink would come off at once. The result was as I said, and he was so pleased that afterwards he invited me into his office, and we gradually became acquainted. I was able to be of some assistance to him, so he raised my salary and kept me working more with him. He put me in charge of all new and experimental work, and I had to look after the men, make patent drawings, and see that everything was properly done at the factory. I studied every night until after midnight, and, during the first two or three years there, I wrote a number of scientific papers." The article is illustrated by the very characteristic reproduction of a photograph of Mr. Steinmetz.

## *Book Reviews.*

Elektro-Metallurgie: Die Gewinnung der Metalle unter Vermittelung des Elektrischen Stromes. By Dr. W. Borchers. Third edition, enlarged and entirely revised. Leipzig, 1902. Erste Abtheilung. Pages, 288. Price, 9 Marks.

This first part of the third edition of Dr. Borchers' well-known work will be doubtless accorded a favorable reception because of the excellence of the previous editions and the reputation of the author. The author takes for granted the reader's familiarity with the nomenclature, laws and paraphernalia of electrochemistry, and plunges at once, *in medias res*, by commencing on page 1 with the metallurgy of magnesium. This is followed by lithium, sodium, potassium, calcium, strontium, barium, beryllium, aluminium, the cerium metals, copper, and part of the treatment of nickel.

The omission of the introduction, giving a resume of electrometallurgical principles, is doubtless due to the appearance in recent years of so many treatises on the fundamentals of electrochemistry, that the author considered even the briefest introduction superfluous. Its entire omission has, however, given an air of incompleteness to the work, for which no degree of excellence in the subject matter presented can completely atone.

The electrometallurgy of magnesium occupies 20 pages, and is more complete in its details of actual work than any other treatise we have seen. In this essay we find all the practical directions for making the metal most carefully given. One error is the statement that magnesium occurs as silicate "always in combination with other silicates," whereas three of the four minerals named thereafter are simple silicates of magnesium alone—serpentine, talc, meerschaum. In stating that magnesium is used as a refining agent for German silver and steel, the reader should at the same time be advised that there is considerable danger of explosion in so using it, if care is not taken.

In the 42 pages devoted to sodium, almost all the possible and impossible schemes for obtaining the metal are described, but one of the best ways of obtaining sodium from salt, the Acker process of producing sodium-lead alloy, is not mentioned, although it was described in print early in 1902. The process by which the larger part of the metallic sodium at present manufactured is made, the Castner process, is treated altogether too briefly, a description of the apparatus being given, but no mention made of the fact which is the kernel of Castner's process, viz., that the caustic must be electrolyzed *within 25° of its melting point*, in order to get any metal. If Dr. Borchers has been compelled to condense, because of the great extent of the field he attempts to cover, there are a hundred things given regarding sodium, any one of which should have been omitted to make room for this description of the basic principle of the Castner process.

In the 70 pages given to aluminium, Dr. Borchers sees the Heroult and Hall processes in a much better light than in his previous editions. His presentation is much fairer than before, and by the time that a fourth edition of this work is prepared for the press there is a reasonable hope that Dr. Borchers will have entirely straightened out the relation of these processes to each other and to the previous state of the industry. He places the Minet process where it rightly belongs, as an inoperative process, and even abates some of the extravagant claims made in a previous edition for the experiments of one Dr. Borchers.

The treatment of copper is full and satisfactory, but not quite up to date as regards American practice. The current density used, the method of continuously purifying the bath, the mechanical auxiliaries of our plants and the operating costs, are a little behind what they should be given in a book finished in October, 1902. The information is at least one year in arrears of that date, at least as far as America is concerned; but what is given is accurate and clear, as far as it goes.

Altogether, the book is very readable, the cuts are of that high excellence which accompanies all of Dr. Borchers' publications, the arrangement is clear, the tone is less caustic and more judicial than marked the earlier editions, but we feel a little disappointed at the omissions. Dr. Borchers has done very well—we had expected that he would have done a little better.

Handbuch der Elektrochemie: Specielle Elektrochemie. By Dr. H. Danneel, Aachen. Lieferung I. Halle: Wilhelm Knapp. Price, 3 marks.

The present volume is the first instalment of a large Handbook of Electrochemistry, which will be published by Wilhelm Knapp. The character of the work will best be shown by a list of the subjects, which will be included. These are the following: Theoretical Electrochemistry, by Prof. Dr. W. Nernst, Gottingen; Electrical Measurements, by Dr. E. Bose, Gottingen; Special Electrochemistry, by Dr. H. Danneel, Aachen; Elements and Storage Batteries, by Prof. Dr. K. Elbs, Giessen; Electroanalysis, by Prof. Dr. F. Küster, Clausthal; Electromagnetic Ore Dressing, by F. Langguth, mining engineer, Mechernich; Technical Inorganic Electrochemistry, by Prof. Dr. W. Borchers, Aachen; Technical Organic Electrochemistry, by Prof. Dr. K. Elbs, Giessen; Electroplating, by Dr. H. Stockmeier, Nurnberg. The parts treating about electrical measurements, electromagnetic ore dressing and electroplating will be issued complete, while the other parts will be published in instalments, the price of each instalment being set at 3 marks. The volumes and single parts can also be bought separately.

The publication of the whole work is expected to be finished in about two years. The aim of the book is to give full and complete information about every electrochemical reaction known up to the present time, its origin, its theory and application. Electrical measurements and electromagnetic ore dressing are included in order to give as complete a review as possible of all branches of science, touching the domain of electrochemistry. The firm of Wilhelm Knapp, which have for a number of years been well and favorably known by the books they have brought out on electrochemical subjects, are to be congratulated on their enterprise in bringing out an encyclopedic work, of the scope proposed. The list of the authors of the various parts, containing, as it does, names well known in electrochemical circles, give good reason to expect that the treatment of the subjects will be thorough and up to date. There is no need to dilate upon the want existing for such a hand-book, in which the information, which is at present widely scattered through a number of journals and patents, will be grouped together in comprehensive form. That such a want does exist is apparent to everyone interested in the subject, and the book will therefore be welcomed by the electrochemical public.

The part on "Special Electrochemistry," of which the present volume is the first instalment, will be complete in about 14 instalments. It is stated, that besides the compilation of the anorganic electrochemical reactions, which have become known up to the present, and a collection of the literature appertaining to them, there shall be collected data and literature about conductivity, polarization and changes of free energy in reactions (electromotive forces and single potentials). Part I bears the title: "Special electrochemistry of the elements and anorganic compounds. Their preparation by electrochemical means and their electrolysis." The volume under consideration is devoted to the treatment of hydrogen, water, hydrogen peroxide and various acids, chief among which are hydrochloric, sulphuric, persulphuric and nitric acids. These are taken up in their historical development, and a large number of literature and patent references are given. Their formation by means of electrolysis and their decomposition by the current is described in detail.

Handbuch der Elektrochemie: Electromagnetischi Aufbereitung. By Victor Langguth, mining engineer Mechernich: Wilhelm Knapp. 64 pages. Price, 3 marks.

This part of the German Hand-book of Electrochemistry is a comparatively short one. The author treats the subject in the following divisions: Development and importance of electromagnetic ore dressing; principles of electromagnetic separation; electromagnetic separators, (1) with movable magnets, (2) with fixed magnets, results obtained by electromagnetic ore dressing. The author has had considerable experience with magnetic separators, in his connection with the Mechernich Bergwerks-Actienverein, the constructors of the Mechernich type of separators and has treated the subject in a clear and concise style. As the book only comprises 64 pages, it is evident that the discussion of the various types of separators had of necessity to be cut short. It is to be regretted that the book has not been expanded to twice or three times its size, and that not more practical data have been included as to the detailed construction of the various types, their capacity, price and results in practice. The growing importance of the subject would certainly have warranted such a treatment. The author being an interested party and apparently favoring the separators constructed by the Mechernich Bergwerks Actienverein, has yet endeavored to treat the other systems from an impartial standpoint. He reaches the following conclusion on page 40: "For the separation of feebly-magnetic bodies we have the systems of the Mechernich Bergwerks-Actienverein and of the Metallurgische Gesellschaft, as owner of the Wetherill patent. The working of the separators is so different, as are also the difficulties which had to be overcome in the two systems, that only the comparison of results obtained on a large scale by the latest constructions of both companies, can furnish a definite basis as to the superiority of the one or the other."

## AMERICAN AUTOMOBILE BATTERIES.—II.

*Continued from page 292.*

### The Madgin Battery.

This battery is only manufactured at present in Canada, although large quantities are being exported to the United States and foreign countries notwithstanding the heavy tariff duties on this class of goods. It is manufactured there under Madgin patents by the Croftan Storage Battery Co., Toronto, Canada, which are the only firm manufacturing storage batteries in the Dominion of Canada.

The construction of the plate in this battery is shown by figures No. 1 and No. 2. Figure No. 1 shows the grid, which, as will be noticed, is made of one thin piece of sheet lead ½ inch thick. This sheet is highly perforated with over 11,000 holes to the square foot, and is horizontally corrugated so as to present parallel ridges about ⅛ inch apart. The positive plates are corrugated to such a depth as to render the plate ⅛ inch thick when finished, and the negative plate ¼ inch thick. In the process of manufacture a rim and lug are burned on at the operation so as to form a border of ¼ inch all around the plate. Fig. 2 shows a positive plate fully pasted and formed, and, as will be noticed the grid is almost entirely covered by the active material with the exception of the small protuberances of the corrugations which present themselves on the outside surface of the plate. In this manner the grid in itself is almost entirely protected from dangerous electrolytic action, which always causes rapid deprecation and disintegration.

The positive grid of their standard automobile type weighs but 10 oz., and when pasted and fully formed will give a discharge of 24 ampere hours at a five-hour rate. The positive plates before pasting are coated with a thin coherent layer of lead peroxide by electrolysis, and are then removed from the solution and pasted with usual oxides, with the addition of a chemical (the nature of which they withhold), which renders the active material extremely hard and yet highly porous. After pasting the plates are subjected to the regular forming process.

In assembling the elements the positive plates are enveloped with a layer of pure fibrous cellulose, which is chemically treated so as to render it neutral and at the same time to guard against disintegration. The plates are then stacked closely together, with the cellulose envelope separating each, and are then connected or burned together in the usual manner.

It will thus be seen that this method of insulation gives a complete perfectly-porous insulating wall between the plates, and if the cell is only half full of electrolyte (which often happens when batteries do not receive proper attention) the entire surface of the plates will remain in action, owing to the juxtaposition of the insulating material and the capillary attraction resulting in the use of this method of insulation. It also prevents any active material from possibly becoming dis

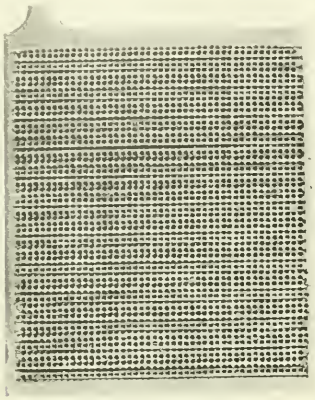


FIG. 1.—GRID UNFORMED.

engaged from the grid, and, furthermore, eliminates all washing action of the electrolyte on the plates, which has heretofore been one of the greatest difficulties to be contended with in automobile practice, owing to the usual excessive vibration while in operation.

From the construction employed it must be noticed that notwithstanding the extreme lightness, as well as the extraordinary elasticity which has been attained, durability has not been sacrificed, but on the contrary is always in evidence. The battery requires but a small portion of the space usually demanded by storage batteries, owing to the compact nature

FIG. 2.—GRID FORMED.

of the elements and the small but sufficient quantity of the electrolyte employed. As an illustration, their 13-plate cell occupies but a space of $2^5/_8$ inches x $6^1/_4$ inches x 9 inches high and weighs but 18 pounds. This cell has a capacity of 132 ampère hours when discharged at the unusually high rate of 35 amperes. This feature is due very much to the perfect contact of the active material with the grid, as well as the extremely low resistance of the grid itself, which admits of discharges much higher than this amount without depreciation. The practice, however, which they employ is to furnish batteries of such capacity as to give from six to eight hours' operation at normal load. In this manner a mileage of 80 miles per charge is easily secured by ordinary vehicles with a battery weighing less than has usually been employed.

This firm also manufactures a patent removable and non-

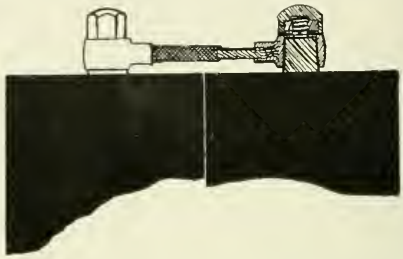


FIG. 3.—FLEXIBLE REMOVABLE CONNECTION.

corrodible connection for automobile batteries, which is flexible and has a large number of advantages over the usual method. By its adoption any cell or set of cells may be removed or replaced instantly without the necessity of sending the entire set of batteries to the factory to be welded together. This is a valuable feature, when batteries are required to be washed at regular intervals. Fig. 3 shows a cut of this connection as applied to two cells, and also shows its construction. It is manufactured in sizes adaptable for all existing American batteries.

### Clare Storage Battery.

The special feature of the Clare battery, built by the Consolidated Storage Batteries Co., of New Jersey, is the use of earthenware receptacles for holding the active material, constructed as follows: Plates are made of earthenware, of sufficient porosity to allow the electrolyte to pass freely through them, and at the same time free from impurities, which would make the substance a conductor.

Each plate is divided on one side into many small, square windows by narrow ribs, the active material being pressed into these windows; the other side of each plate has parallel ribs in one direction only. Each plate also has a heavy rib on one or two of its edges, extending slightly further from the plate than the smaller ribs which form the windows containing the active material.

When two such plates are put together, so that the windows face each other, there is thus a small space left between them opposite windows, and into this space a thin sheet of pure rolled lead, about 1-32 inch in thickness, is forced, so that it comes into intimate contact with the active material in each window. This sheet of lead serves only for collecting the current from the active material, and not as support.

The heavy ribs at the edges of the plates are cemented together by an acid-proof cement. A pair of such earthenware plates, joined together in this way, forms a receptacle of rigid structure, which represents a single positive or negative element of a battery.

The principal advantages claimed for this construction are lightness and durability of the plates, with sufficient porosity to allow the electrolyte to pass freely through the sides of the receptacles; the internal resistance is very low, and the active material is so firmly held in the receptacles that it cannot fall out. The receptacles are also sufficiently elastic to allow for all expansion of the active material.

Concerning weight and capacity, the manufacturers state that their batteries made for automobile work give 5 ampère hours per pound of cell complete.

## SLATE FOR ELECTROCHEMICAL USES.

The value of slate as a material for resisting certain chemicals has long been recognized by manufacturers. In the preparation of bleaching powder from chlorine procured by the Deacon process, large quantities of slate are used in the construction of the bleach chambers. Lime is spread on slate shelves, and the chlorine caused to pass over them.

With the advent of electrolytic processes for the treatment of brines, slate was soon found to be a most admirable material. Its chemical composition is such that alkaline solutions and bleach liquors have almost no action on it. Hence it has been extensively applied to the cells used in the manufacture of chlorine and caustic soda. Especially to that class of cell known as the diaphragm type.

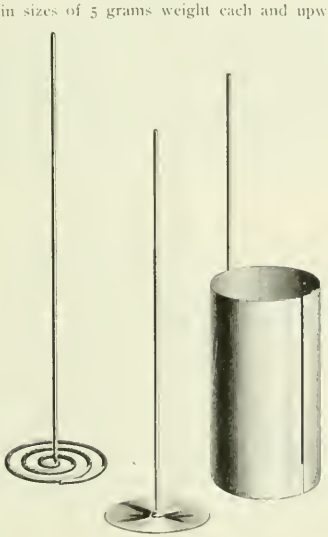
In these cells it has been found satisfactory as a material for constructing the tanks, as a covering for the gas space, and as a support for the electrodes.

A slate to fulfill the requirements of this work must be free from mineral veins, soft enough to permit ready working, and at the same time possess sufficient resistive properties to enable it to withstand the action of alkaline brine solutions. Obviously it should be free from check cracks.

The slate quarried by the American Slate Co., of Boston, Mass., has been found to fill these requirements in a most satisfactory manner. Cases have been observed where this slate has been immersed continuously in electrolytic baths for years without showing signs of deterioration, except for a slight discoloration. This fact, together with its resistance to attack by chlorine is sufficient to explain the marked favor with which it is regarded by the manufacturers using the recently developed electrolytic processes.

## PLATINUM ELECTRODES.

Messrs. Baker & Co., the platinum refining firm of Newark, N. J., report a constant increase in the demand for various forms of platinum apparatus made by them for electrolytic purposes. Fig. 1 to 8 show various forms of platinum electrodes for electrolytic separations. Electrodes, 1, 2 and 5 are furnished in sizes of 5 grams weight each and upwards; the standard form of electrode, Fig. 1, has a spiral 2 inch in diameter. Fig. 3 and 4 represent electrodes in the form of a closed and an open cylinder, respectively, of an approximate weight of 8 grams each and upward; the standard size is 1 inch in diameter, 2 inches high, the weight being 11 grams. Fig. 6 to 8 show electrodes of a weight ranging from 20 to 50 grams. In addition to these and other simple forms of platinum electrodes for laboratory separations, Messrs. Baker & Co. build to specifications all sizes and shapes adapted to individual requirements.



FIGS. 1, 2, 3.—PLATINUM ELECTRODES.

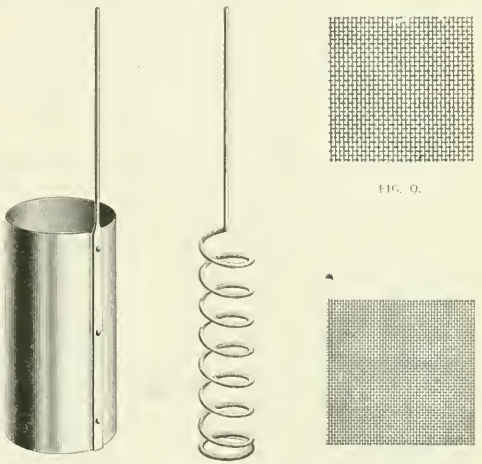
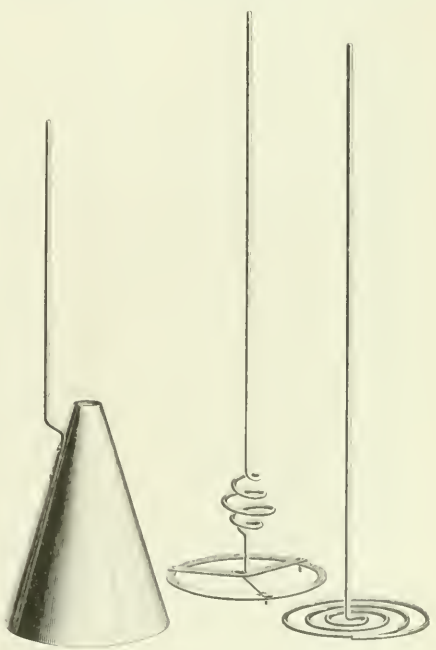


FIG. 4. FIG. 5. FIG. 9. FIG. 10.

PLATINUM ELECTRODES.

The present tendency to use platinum-gauze electrodes, both for laboratory and commercial separation, is rapidly growing in favor, because of the many advantages they offer over the solid sheet type. Greater uniformity of current density per unit of surface, and hence less variation in depth of deposit



FIGS. 6, 7, 8.—PLATINUM ELECTRODES.

are adorned with gauze electrodes. Free escape of disengaged gases and deposit of the metal completely encircling the individual wires of the mesh practically prevent peeling losses. Finally, greater current density can be employed, thus reducing the time required for effecting separation. Such platinum-gauze electrodes are represented in Fig. 9 and 10. The two standard sizes, kept in stock by Messrs. Baker & Co. are 45 mesh, 0.0085-inch wire, weight per square inch 1.500 grams, and 52 mesh, 0.004 inch wire, weight per square inch 0.543 gram.

## GENERATORS FOR ELECTROPLATING, ELECTROTYPING AND OTHER ELECTROLYTIC WORK.

In our September issue we gave an illustrated description of several modern types of Eddy electroplating dynamos. In the following we will give some supplementary information on these Eddy machines which are now made by the General Electric Co.

These, machines, as now manufactured, run at low speeds, are cool under continuous operation at full load, and are little effected by change of load in the baths. No change in lead of the brushes is required for variation in load. The standard generators for electroplating and electrotyping are built in six sizes. The smaller sizes have a frame consisting of a rectangular steel casting to which are bolted two steel poles. The larger sizes are of the multipolar type. The frames are of cast steel made in one piece, to which are bolted cast-steel pole pieces.

The multipolar type is well adapted for the larger sizes, where the brush contact is necessarily large in order to collect the heavy current with a minimum of heating and loss in resistance. The shaft between the bearings is short and of sufficient size to entirely eliminate springing when subjected to the sudden overloads which very often occur when the machine is accidentally short-circuited at the tanks.

The pole pieces are of such a shape as to minimize the magnetizing energy required in the field coils to produce a powerful field of force. The section under the coil is small in comparison with the area exposed at the air gap, and the projecting pole tips are so proportioned that a conductor of the armature enters a field of gradually increasing density rather than one in which the change is abrupt at the pole corners. This feature of the design prevents polar heating, eliminates the disagreeable magnetic hum so often experienced, and forms a fringe of magnetic lines in the neutral point for the reversal of the current under commutation.

The field coils are wound on forms, thoroughly insulated, taped and baked. They can be easily and quickly removed from the poles in case of accident.

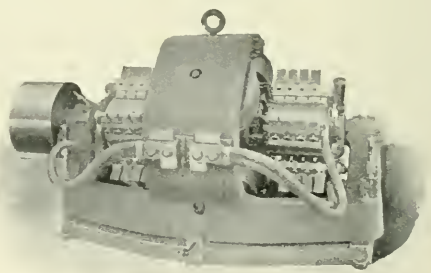
The commutators are built up of copper strips, insulated from each other by mica, and are so constructed that it is impossible for the strips to become loose and cause the brushes to jump, a condition which necessarily produces sparking and its consequent wear of commutator and brushes. On the larger sizes, openings in the heads, and air passages in the armature core allow a free circulation of air through the commutator and armature.

The tangent type brush-holders firmly clamp the brushes and insure good contact. The brushes are of woven wire, which is superior for conveying the heavy current at a low voltage with a minimum loss in resistance. They greatly reduce the wear of the commutator by retaining lubrication, and require very little attention. The brushes on all the machines are of sufficient size and number to carry the full current with little rise in temperature above that of the surrounding air. This is an essential feature, since less attention is required to keep the commutator and brushes from wearing, when the oil does not become overheated, so as to lose its lubricating properties. The adjustment of the brushes is very simple and can be quickly accomplished.

The armature core is made up of sheets of best annealed iron, and is firmly held in place by iron heads. Air ducts lead from the centre of the core to the circumference, providing thorough ventilation for all parts. The bar-wound type of armature which is used is well adapted for this class of machinery and forms a practically indestructible winding. It reduces the danger of burn-outs caused by accidentally overloading the machine, and is not likely to be injured by rough handling. The winding, which is heavily insulated, and connected at the ends by copper ribbons, is inserted in an insulated slot cut in the core, and is entirely below the surface. In case of accident to one or more bars they can be easily removed without disturbing the remainder of the winding. All connections between the armature winding and the commutator are soldered. When screws or bolts are used they are liable to become loose or corroded, thus increasing the resistance of the armature, and causing sparking between the commutator and brushes.

The voltage of both self-excited and separately-excited machines is regulated by a rheostat in the field circuit, which is intended to keep the voltage constant for all changes in load, but will not reduce the voltage more than 25 per cent. from the maximum rating.

In the larger machines the load sometimes varies between wide limits, owing to the introduction or removal of work at the tank. With a self-excited machine this would require constant manipulation of the rheostat to keep the voltage constant, while with a separately-excited machine the voltage will remain practically the same. With the larger sizes, therefore, a separate generator to excite the fields of the machine is furnished. If, however, a continuous current line of any of the standard voltages is available the fields of the machine may be excited from this line, and no exciter will then be required.



ELECTROPLATING DYNAMO.

So-called double-voltage machines are made with two commutators, one at each end of the armature. The armature has two distinct windings each connected to its own commutator, and by proper connection at the terminals the voltage of the output will be equal to the sum of the voltages of the two commutators, and the current that given by one; or the voltage may be made that of a single commutator, and the current that given by two. For example, with a machine having a voltage of 5 and a current of 1,200 ampères, by a different connection a voltage of 10 and a current of 600 ampères can be obtained without change of speed. When both voltages are required at the same time the machine will take the place of two separate machines, and use only about one-half the amount of copper in the line. The total current used with the high voltage, plus one-half the total current used with the low voltage, should not exceed one-half the maximum current of the machine. For example, suppose a machine to have a maximum output of 1,200 ampères at 5 volts; it would be possible when connected on a three-wire system to draw a current of 1,000 ampères at 5 volts, and another of 100 ampères at 10 volts.

The three-wire system of distribution when used with these machines effects a very large saving of copper, and a marked improvement of voltage at the tanks when work is introduced or removed.

The accompanying illustrations represents a double voltage machine, giving 600 or 300 amperes at 5 or 10 volts respectively, when running at a speed of 650 revolutions. The power required for driving it is 6 horse-power.

## POTTERY WARE FOR ELECTROCHEMICAL PURPOSES.

In almost all electrochemical work, not only in experimental laboratories, but also in work which is done on a commercial scale, one of the most indispensable requirements is reliable material in the way of chemical pottery ware. For the past twenty-five years the Charles Graham Chemical Pottery Works, of Brooklyn, N. Y., have been turning out this class of material; in fact the entire plant is devoted solely to the manufacture of this line of chemical apparatus.

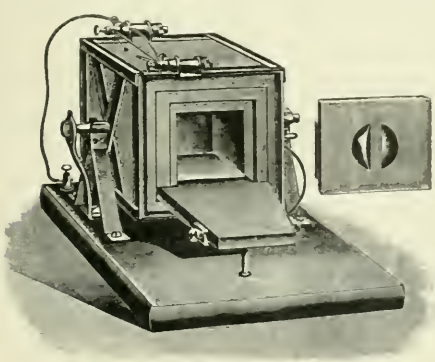
The illustrated catalogue recently sent us by Mr. Charles Graham, gives a great number of pottery apparatus of various forms and for various purposes, such as pots and tanks, acid towers, distilling apparatus, stoneware coils, retorts and condensing worms, chlorine apparatus, water lute receivers and connecting pipes, faucets, spigots, and valves, all kinds of jars, pitchers, dishes, etc.

This firm also makes acid-proof vessels to the size of 500 gallons, and any kind of vitrified stoneware chemical apparatus, such as receivers, arms, connecting pipes, crystalizing and evaporating dishes, acid pitchers, funnels, glazed acid bricks, carbon stoppers, etc.

Mr. Charles Graham also manufactures special apparatus to order. Several pumps made by him for the Canadian Copper Co. were described in the interesting paper of Mr. David H. Browne, read at the Niagara Falls meeting of the American Electrochemical Society. They are of a very compact form. An illustration of this type of pumps may be found on page 231 of Vol. II. of the Transactions of the American Electrochemical Society.

## ELECTRIC FURNACES, PLATINUM WARE AND FUSED QUARTZ APPARATUS.

The firm of Messrs. Eimer & Amend, of New York City, report that they have recently made important progress in the construction of electric furnaces, both for direct and alternating current. The most improved recent forms, one of



ELECTRIC FURNACE.

which is shown in the adjoining illustration, will be shown and described by Mr. A. Eimer, of Messrs. Eimer & Amend, at the coming New York convention of the American Electrochemical Society.

Messrs. Eimer & Amend are also manufacturers as well as importers of balances of the finest quality, especially for electrochemical work. They are also very large dealers of platinum ware in various forms and makes, including United States Mint parting apparatus. They have large facilities for making platinum electrodes and platinum vessels of every design. As something new, they refer to their new platinum carbon determination apparatus, and also to the carbon determination apparatus, with electric ignition arrangement, with no platinum metal used. They also keep an extensive stock of electric outfits for stirring machines, centrifuges, etc.

Among the most interesting exhibits which will be shown to the members of the American Electrochemical Society, there will be various quartz ware, such as crucibles, flasks, tubes, test tubes, breakers, dishes, thermometers, etc. Quartz is known to be among the best insulators and withstands at the same time extremely large changes of temperatures. One of the simplest and most convincing experiments is to heat a small flask of fused quartz to white heat and then pour water into the white, hot vessel, without the least harm being done to the vessel. Another property of this fused quartz is that it is not hydroscopical, and that it is not attacked by many important chemical reagents, which is of great importance for many purposes. These quartz apparatus will be of special interest, in view of Mr. R. S. Hutton's paper, read at the Niagara Falls meeting of the American Electrochemical Society on the fusion of quartz.

A special visit of the members of the American Electrochemical Society to the show rooms of Messrs. Eimer & Amend have been arranged for the Thursday afternoon, April 16th.

## THE ELECTROLYTIC DECOMPOSITION OF WATER AND ITS APPLICATIONS IN INSTALLING STORAGE BATTERIES.

In recent years the use of the oxyhydrogen flame has been widely introduced into practice for various purposes for which formerly hydrogen, generated by the action of sulphuric acid upon zinc, together with compressed air had been generally used. The main advantages are: first, the higher temperature of the oxygen hydrogen flame, which enables one to finish a given work in a shorter time, and, second, the great convenience of electrochemical methods for generating the oxygen and hydrogen required for the oxyhydrogen flame. Especially for installing storage batteries the oxyhydrogen flame has great advantages in assembling plates together, and joining the edges of the lead lining in tanks, or in general for making any lead joints or connections.

The use of compressed oxygen and hydrogen is to be recommended wherever relatively small quantities of the gases are used at one place. On the other hand, if at one place the oxyhydrogen flame is to be used continually, every day, it would be uneconomical to pay for the compressions of the gases, the tanks and the freight, and it is much cheaper to install an electrolytic water decomposition plant.

When water, in which an acid or an alkaline is dissolved is decomposed by the electric current, one ampere hour produces theoretically 0.0379 grams of hydrogen and 0.298 grams of oxygen, or 418 c. c. of hydrogen and 209 c. c. of oxygen (under atmospheric pressure). The only difficulty in the construction of the electrolytic decomposition plant is to prevent the danger of explosions due to the mixing of the two gases oxygen and hydrogen.

In the following we give a description of the Schoop system as installed by the Koelner Akkumulatoren Werke, Gottfried Hagen, Kalk, near Cologne, Germany. The characteristic feature of this system is that the electrodes are made in the form of tubes, the outside of which is coated with a layer of insulating material. These tubes are placed side by side in the electrolyte, and as only their inside surface is conducting, the development of gases can only take place in the inside of the tubes. The use of tubes has the further advantage that their

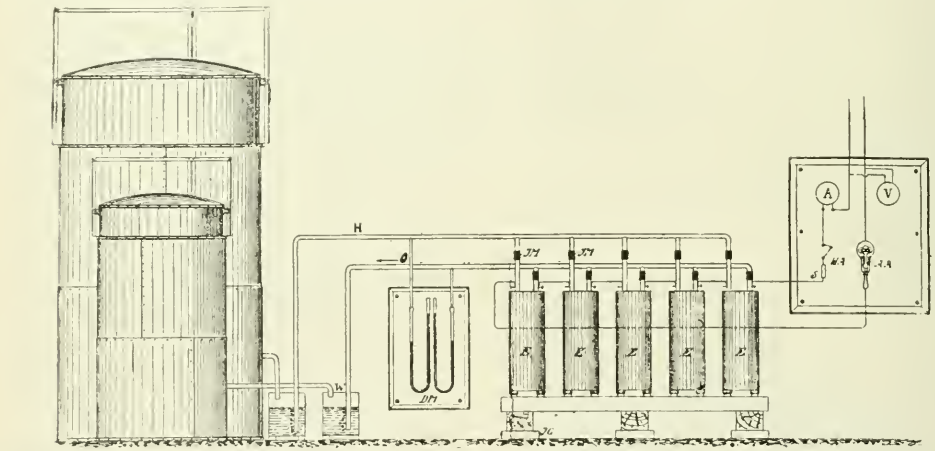
length may be so adjusted that the gases escape from the tubes directly under the pressure which is wanted—in general that of column of water of 60 to 70 cm height—so that no artificial compression of the gases is required.

These tubes may be made of iron for an alkaline electrolyte, and of lead for an acid electrolyte; but in practice it has been found that an acid electrolyte is greatly preferable. In the Schoop system pure sulphuric acid of a specific gravity of 1.23 is used.

Each electrode consists of three parts; a larger one of the form of a globe in which the current passes into the acid; a lead body of large surface which is placed inside of the globe and serves the only purpose of increasing the acting surface; and a tube at the top of globe which serves as electric connection for the globe, and at the same time as exit tube for the developed gases. The length of the tube depends upon the pressure under which the gases are to be developed. For such a tube with a globe of about 90 mm diameter a current of 25 ampères may be continually used, so that per hour 10.44 liters of hydrogen and 5.22 liters of oxygen are generated. The tubes are placed in a box, the inside of which is coated with lead; a series of positive tubes is always placed at the side of a series of negative tubes. Below the tubes there is a space for collecting the fine powder of lead peroxide which drops down from the positive electrodes.

The purity of the gases is great; oxygen is guaranteed to contain 99 per cent. of oxygen and contains much ozone when freshly developed; the balance of 1 per cent. is steam. The hydrogen is guaranteed to contain 97.5 to 98 per cent. of hydrogen. If for therapeutic purposes the oxygen must be free of steam, is only necessary to let the oxygen pass through concentrated sulphuric acid.

The advantages of the system are stated to be the following: absolute safety of operation and prevention of explosions; if the electrical connections are made correctly, there are no interruptions of service or repairs, as diaphragms of asbestos, etc., are not used; the gases are nearly chemically pure; the attendant has to do nothing but to fill in pure water at intervals. A small disadvantage of the system is the use of more electrical energy than in other systems, as there is a counter e m f in the apparatus, which behaves like a charged storage battery of small capacity.




WATER DECOMPOSITION PLANT

The apparatus is shown in the adjoining diagram in which E is the electrolyzer, A an ammeter, V a voltmeter, H A a hand switch, A A an automatic circuit breaker, B a fuse, I M an insulating joint, and D M a device for measuring the pressure.

The apparatus requires no attendance with the only exception of distilled water being filled into the apparatus about once a week. The voltage of operation is about 3.3 to 3.6 volts per cell, according to the current density used and the temperature of the electrolyte. In connection with a 110 volt installation about 30 electrolyzers are connected in series, the gas exit tubes of the different cells being connected with the tubes for collecting the gases by means of insulating rubber tubes.

An installation of this kind has been in continuous use since January, 1902, giving per electric horse-power 97.5 liters of hydrogen and 48.75 liters of oxygen, *i. e.*, one cubic meter of the mixed gases requires 6.8 horse power hours. With warm acid this energy consumption is reduced to 6.2 horse-power hours. If the cost of one horse power hour is assumed to be 1 cent, the cubic meter of the mixed gases costs 4.2 to 4.8 cents.

## *Personal.*

Dr. Walther Nernst, the distinguished professor of electrochemistry at the University of Goettingen, Germany, and the inventor of the Nernst lamp, will participate in the proceedings of the American Electrochemical Society, as already noted in our last issue. Dr. Nernst is due to arrive in New York City about April 3d, from Europe.

The well-known electrometallurgist, Mr. Titus Ulke, has accepted the position of assistant to the manager of the Clarion and Highland Mills of the New York and Pennsylvania Co. This note is here repeated in order to correct a typographical error in our last issue.

Assistant Professors Dr. W. D. Bancroft and Dr. F. Merritt have been promoted to full professorships of physical chemistry and physics, respectively, in Cornell University.

Mr. G. D. Case has resigned as superintendent of the Washoe smelters of the Amalgamated Copper Co. at Anaconda, Mont., and has accepted a similar position with the Copper Range Co., near Houghton, Mich.

Mr. Hugh Rodman, of the Electric Storage Battery Co., is spending a month in Orlando, Ky.

The Boston Society of Civil Engineers has elected Prof. Ira N. Hollis as president. Prof. Hollis holds the chair of engineering at Harvard University.

Mr. J. Parke Channing is in the City of Mexico.

## INDUSTRIAL NOTES.

The Metals Recovery Co. have recently been organized in Philadelphia, with a share capital of $1,250,000, consisting of $250,000 in 7 per cent. preferred and $1,000,000 common stock. The president of the company is Dr. N. S. Keith, of New York City, who has transferred to the company his patents 597,820, of January 25, 1898, for an electrolytic gold and silver process; 700,941 of May 27, 1902, for an electrolytic copper process, and 714,914 of December 2, 1902, for a new process of winning metals from their ores. The latter process which is not electrochemical, shall be employed at the first reduction works of the company, to be erected at High Hill, Virginia district, Va., at the mines of the Virginia Copper Co. The process of Dr. Keith consists in grinding the ores and their gangues to the necessary degree of fineness, and after mixing the ground materials with comminuted carbon—such as ground coal, ground charcoal, or petroleum—he heats them in a suitable furnace to the degree of fusion of the particles of ores. The resulting metallic substances which have a more or less globular shape, are separated from gangues by any suitable method of concentration; on account of their globular shape they are more readily and effectively separated from the gangues by concentration. In the prospectus of the company it is estimated that the cost of operation per ton of copper ore (including crushing, mixing, furnace operation, concentrating, and putting the metal into bars) is $1.50 at High Hill, Va.; the copper ore at this place contains 5 per cent. of copper, so that one ton of ore yields 90 pounds of copper, which the Virginia Copper Co. agrees to buy at the rate of 6 cents per pound, *i. e.*, $5.40. The cost of operation is stated in the prospectus to vary between $1 and $1.50 in Virginia, and from this figure to $2.50 per ton in Arizona, depending entirely on the cost of coal, power and labor.

The Electric Storage Battery Co., Philadelphia, Pa., have recently closed several large contracts for the installation of storage batteries in connection with street railway work on the Pacific Coast. The Los Angeles Railway Co. have contracted for three batteries, two consisting of 264 cells having a capacity of 1,000 ampères and one of 264 cells having a capacity of 2,000 amperes. The Pacific Electric Railroad have also contracted for a battery of "chloride accumulators," consisting of 264 elements of 1,000 ampéres capacity. Several batteries are now in process of installation for the following roads in the same section: The Oakland Transit Consolidated, the Los Angeles Pacific Railway and the North Shore Railroad.

Electric Storage Battery Locomotives.—The C. W. Hunt Co., West New Brighton, L. I., N. Y., have recently issued a small booklet on storage battery locomotives for use in shops, foundries and factories. Their general construction is described and illustrated, and their advantages are pointed out. While the great weight of lead batteries in proportion to the energy stored by them precludes their use for long hauls or high speeds; but for shop or yard work the increased weight from the batteries is an advantage in giving a great draw bar pull. On tracks substantially level, or with grades frequently found in manufacturing establishments, a battery is a most convenient, economical, and efficient source of power. In almost all cases the first cost of the battery is less than the cost of trolley wires and supports, including cost of erection, if the trolley system were used; and the expense for maintenance is far less than for trolley wires. Furthermore, there are the very important advantages that a battery locomotive can instantly run on any track, regular or improvised, while the trolley locomotive can run only where wires are installed; trolley wires cannot well be run in erecting shops, machine shops, or under over-head cranes, while the battery locomotive is operative wherever a track is laid. The current from the battery is utilized by various combinations of series parallel connections, thus obtaining the different variations of draw-bar pull and speed required for general shop work. Unusually large and heavy battery plates are used, which are not over worked even in starting the load, thus insuring a durability and efficiency of the lead plates equal to that found in stationary batteries in lighting plants. The booklet states that "batteries for automobile work are usually required to deliver about 7 watts per pound of lead, while the locomotive batteries are called upon for only 2 watts per pound." Two independent electric motors are used, connected at will, either in series or in parallel. In another illustrated pamphlet of the C. W. Hunt Co., the employment of the "industrial" railway in the boiler room is discussed.

Messrs. Baker & Co., the platinum refineries of Newark, N. J., have sent us a number of very neat little pamphlets: The Alchemistic Symbols, a brief account of their origin and their meaning, by J. L. Howe; Durable Sparking Points for gas, gasoline and oil engines; Tucker's Combustion Apparatus for determining, with great accuracy, the volatile ingredients and total ash of any organic matter; Shimer's Combustion Apparatus for the determination of carbon in iron, steel, etc.; Sparking Points, jump-spark terminal wires and platinum ignition tubes, for use on automobiles.

The Holtzer-Cabot Electric Co., Boston, Mass., inform the engineering world that the proper care of their dynamo, motor and motor generator specialities now demands all their attention. They have, therefore, discontinued the manufacture of portable, disk and ceiling fan motors of all kinds. This notice does not apply to direct-connected ventilating fan outfits. The Holtzer Cabot Electric Co. are well known to electro chemical engineers by their high-grade electroplating dynamos and in general, by their machines designed for special electro chemical purposes.

Steam Turbines.—A recent computation has placed the total aggregate power of steam turbines in use or under construction or ordered in different parts of the world at over 500,000 horse-power. Of this total the major portion is used or to be used for the driving of dynamos, alternators, or other electrical machinery, while the next in point of power consumption is marine engines. A contract was recently given to the British Westinghouse Electric and Mfg. Co., Ltd., by the Metropolitan District Railway Co., London, England, for four turbo alternators. Each of these machines is designed for a normal capacity of 5,500 kw, but will be capable of carrying an overload of 50 per cent., giving for each unit a maximum output of 8,250 kw, or about 11,000 electric horse power. These turbines will be not only the largest steam turbines ever made, but also the most powerful single cylinder engines of any type whatever in the world. Very few multiple cylinder engines existent have greater power. Notwithstanding the truly enormous power they will develop, the dimensions of these engines are only 29 feet in length, by 14 feet wide, by 12 feet high the overall length of turbine and alternator being 51 feet 9 inches. The steam pressure will be 165 pounds per square inch, and the speed 1,000 revolutions per minute.

Catalogues Received.—Westinghouse Electric and Mfg. Co.: Folder, No. 4,011; Westinghouse fan motors, for alternating and direct current circuits, swivel and trunnion type, a large pamphlet, special publication, No. 7,000, also on the subject of fan motors; both pamphlets are neatly illustrated. Fort Wayne Electric Works: Flyer, No. 4,043 on commutator truing devices; No. 4,044 on fan motors, suspended revolving and desk types; bulletin No. 1,039 on small direct-current generators; No. 1,040 on motor-starting rheostat, with double-release and combined switch and circuit breaker; No. 1,041 on direct current belted motors; a booklet on perfection in transformer insulation. McGuire Mfg. Co.: An illustrated catalogue of their rheostats for various uses. Osborne Flexible Co.: Several flyers on "flex duct" a flexible conduit for interior wiring.

## DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

*Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.*

*This digest of electrochemical United States patents prior to July, 1902, will be one by classes, setting out for comparison in each class those devices which have the same object, or those methods which seek the same results.*

(Continued from page 232)

642,023. January 23, 1900; G. N. Vis, Schweizerhalle, Switzerland.

Removes calcium and magnesium from brine by electrolyzing with a curent sufficient to decompose some sodium chloride, but no calcium or magnesium salts, *e. g.*, 230 ampères at 2.4 to 5 volts per cubic meter for ten hours. The sodium hydroxide produced precipitates the calcium and magnesium. The small proportion of calcium hydroxide which re-dissolves is precipitated by injecting just sufficient carbon dioxide. May precipitate all of the calcium and magnesium as carbonates by introducing carbon dioxide immediately after electrolyzing.

647,217. April 10, 1900; A. J. O. Chalandre, L. J. B. A. Colas and C. J. Gerad, Paris, France.

Passes chlorine and hydrogen from cell of patent 511,682 into an outer chamber, where they combine. Introduces the resulting hydrochloric acid into the anode compartment to neutralize any caustic or decompose hypochlorite.

652,846. July 3, 1900; J. Hargreaves, Farnworth-in-Widnes, England.

Injects spent brine from electrolytic cell, by means of a steam jet, into and upward through a body of salt, which filters out any insoluble impurities and strengthens it for reuse. Shows an electrolytic cell of the Hargreaves type, having an electrolyzing compartment with side walls of lead, coated with pitch, against which a cement backing is cast. A row of superposed, inclined anode bars faces each diaphragm electrode, the space betwen the two rows being filled with salt.

653,933. July 17, 1900; R. Moritz, Lille, France.

Vessel consists of two rectangular support plates having opposing rims, between which a diaphragm of asbestos board or cloth is clamped. Plate at anode side may be of wood, earthenware or enameled iron; plate at cathode side of iron or stoneware. Anode, wire netting, the vertical weft wires of which may be much larger, clamped between anode plate and diaphragm. Cathode, a series of vertical carbon rods, clamped between cathode plate and diaphragm. Electrolyte is introduced on each side of the diaphragm at the lower end of the cell and flows upward in thin sheets, escaping at the upper end of the cell. Anode plate may have vertical grooves behind wire-gauze anode to distribute the stream in a thin, even layer. Carbon rods of cathode effect the same function. The bubbles of gas on the electrodes are washed off by the circulating streams.

655,343. August 7, 1900; J. Hargreaves, Widnes, England.

Improvement on cell of patent No. 596,157. Central anode chamber containing brine, with diaphragms at each side. Vessel consists of a sectional iron frame, lined with Portland cement or brick and cement. Renders lining impermeable by saturating it with paraffin, pitch or tar. Horizontal, transversely-inclined copper strips, arranged in vertical series, are bedded at one edge in the cement lining and bear at their other edges, which are serrated, against the wire-gauze cathodes, which support the diaphragms. Steam and carbon dioxide are injected into the upper ends of each empty cathode compartment and the condensed water is distributed by the serrated edges of the strips evenly over the cathodes, washing down the caustic. Perforated salt-supply device in anode compartment. Decomposes any hypochlorites or chlorates by hydrochloric acid or an oxidizable substance such as sugar or sawdust, introduced into anode compartment. Sides of vessel may be inclosed by wooden planks, to retain heat.

665,064. January 1, 1901; E. D. Chaplin and H. G. Halloran, of Boston, Mass.

Vessel of wood, having a shallow pan, serving as cathode, in its bottom. Horizontal diaphragm of cotton cloth or cloth and asbestos, stretched across upper edge of pan. A series of anode bells, each containing an annular anode of carbon or lead peroxide, depend into vessel. Each anode bell is surrounded by a wooden ring, to the lower edge of which is secured a diaphragm of cotton cloth, or cloth and asbestos, closing lower end of bell. Salt saturator in each anode bell, consisting of a porous bag, having a supply tube with feed screw.

665,953. January 15, 1901; A. J. O. Chalandre, L. J. B. A. Colas, of Paris, and C. J. Gerard, of Sevenx, France.

Process corresponding to No. 647,217. Burns a sufficient amount of the evolved hydrogen and chlorine to decompose hypochlorites, when added to anode compartment. The amount of hydrochloric acid so produced is preferably 5 to 40 per cent. of the amount of caustic produced in the same time.

666,221. January 15, 1901; D. N. Hathorne and H. E. Hobson, Rumford Falls, Maine.

Diaphragm, a bag of asbestos, supported in a perforated sheet-metal vessel serving as cathode, which in turn is supported by legs in a tank. Drain pipe leads through lower end of diaphragm and cathode vessel. Tubular carbon anode, divided into four spaced sections, which are arranged near diaphragm. Centrally arranged salt saturator, consisting of a perforated, bulb-shaped earthenware vessel, removably secured to the lower end of a feed tube. Coats those portions of the diaphragm and cathode vessel which extend above the electrolyte with an inert paint.

669,441. March 5, 1901; H. A. Frasch, Hamilton, Canada.

Anode, a layer of carbon plates, lying flat on bottom of vessel and covered by a layer of matte or ore. Diaphragm, a layer of sand or ground quartz, resting upon the matte. Cathodes of carbon or copper, depending into upper portion of vessel. A pair of inlet and outlet pipes at each side of the vessel, both above and below diaphragm. Several cells may be connected in series. Circulation of electrolyte beneath diaphragm in opposite direction to the above diaphragm. Electrolytic chlorine or sulphuric acid, dissolves metal of matte, such as copper, nickel or iron, while caustic is produced at the cathode.

675,749. June 4, 1901; A. Merry and J. H. Noble, Liverpool, England.

Porous cup of earthenware, inclosed by a copper wire-gauze cathode. The cup is hermetically closed at its upper end and the brine is maintained under pressure by a suitable head, so as to force the caustic out through the pores of the cell and maintain a strong brine solution in them. Brine continuously circulated along inner wall of porous cell; may be introduced through a passage in the anode, escaping at its lower end, and being delivered from the cup through a second passage in the upper end of the anode. A tubular baffle of porous material, or a vertical series of inclined glass louvers, surrounds the anode and serves to keep chlorine away from the diaphragm. Outer vessel may contain water, if caustic is desired, or oil or other soap-making material or acid which it is desired to unite with the base.

680,191. August 6, 1901; E. A. Allen, Rumford Falls, Maine, and H. K. Moore, Lynn, Mass.

Anode chamber, a vessel of clay or iron, lined with porcelain, clay, graphite, or a chlorine substitution product of benzine. Lower end of anode chamber closed by a diaphragm of asbestos paper or cloth, beneath which is a spongy cathode of several layers of iron-wire cloth or of iron turnings or borings, resting on an iron grid. Anode, a body of broken carbon or graphite, resting on the diaphragm. Brine delivered by a float-feed device through a tube opening at the upper surface of the anode. Electrolyte continuously percolates downward through the diaphragm and exposed cathode, oxidizing and washing out the sodium.

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## NEW YORK MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The third general meeting of the American Electrochemical Society, held at New York City, from April 16th to 18th, turned out to be, as a whole, the most successful meeting which the Society has had, especially in its social features, which had been admirably arranged by the local committee. The attendance was large, the number of members and guests who registered being 200. The enthusiasm of the members and the cordial relations between the various classes of workers in the electrochemical field were the same as in former meetings. This is most important, as it proves that the vigor and enthusiasm displayed so conspicuously at the Philadelphia and Niagara Falls meetings were not simply due to the "nascent state" of the Society, but that the Society really fills a need.

It is a matter of special satisfaction that at its New York meeting the young society entered into cordial relations with some of its chemical and electrical sister societies. The Chemists' Club, which tends to become the New York center of the whole chemical activity of this country, extended the hospitality of its club house to the Society, and the American Institute of Electrical Engineers invited the American Electrochemical Society to a joint meeting, at which an excellent experimental lecture by Mr. Hammer, on some subjects relating to the borderland of science, was greatly enjoyed. We hope that this will turn out to be only the first of a long series of joint meetings, and that in this way the American Electrochemical Society will become an important factor in bringing chemists and electrical engineers together. The advantages which may be obtained from such intercourse for both chemistry and electrical engineering cannot be overestimated.

On the following pages we give a complete account of the proceedings, and it is sufficient to state here that the technical programme was of the same high order as at the former meetings. There was again a long list of good papers on timely and important electrochemical subjects. In fact, the technical programme was rather too much crowded. The inherent disadvantage of a crowded programme is that the discussion falls short. Several important papers read in New York were not discussed at all. This is greatly to be regretted, because a good general discussion is equally as important as a good paper. Points which an engineer would not like to put into a paper for commercial or other reasons are often brought out in a discussion. A good discussion is the ideal supplement to a good paper.

The main condition by which a good general discussion is made possible is that the papers are printed in advance and sent to the members before the meeting. The first step in this direction was made at the New York meeting with some of

the papers, although the "advance copies" arrived after several of the papers had been read, so that the real object of printing a paper in advance was not accomplished. Anyhow, the first step has been done in the right direction, and we trust that at future meetings advance copies of a greater number of papers will be in the hands of the members before they leave their homes for the place of meeting.

Among the papers on more practical subjects there were three on various details of the electrodeposition of metals, one on copper refining, one on the electrolytic production of metallic compounds, especially white lead, two on storage batteries and one on the corrosion of metals by electrolysis. In another paper the search for an insulating material of all-around perfectness was pointed out to be a promising field for chemical investigations. The balance of the papers were of a more theoretical nature. We are glad to note that discussions of questions of physical chemistry meet with the interest of the members of the Society. Physical chemistry is not a branch of chemistry, like analytical chemistry; physical chemistry is general chemistry.

About half the number of the authors were practical or consulting engineers; the other half represented American universities. The University of Wisconsin alone was represented by six authors, with four papers in all. The other American universities represented by papers were Cornell, Lehigh, University of Michigan, Johns Hopkins and McGill University. While it is perfectly true that, as Dr. Richards remarked in his presidential address, we are out of comparison with Germany with respect to the number of chairs of electrochemistry and well-equipped electrochemical laboratories, yet it must be said, on the other hand, that the splendid and vigorous activity of a few American universities in the field of electrochemistry is all the more conspicuous.

We said above that the programme of the New York meeting was somewhat too crowded. The most certain remedy for the future would be to carry into effect a suggestion which was put forward by us in these columns in our last issue, and which was also advocated in the official report of the secretary, Mr. C. J. Reed. Mr. Reed pointed out that while it may still appear to be too early now to do anything towards the establishment of local branch organizations, yet, at the present rate of increase of members, such local branches may very soon become desirable, if not a necessity. If we may use the terminology of electric central-station engineers, we may say that the load curve, representing at present the work of the Society, is nearly at zero for the greatest part of the year, and shows two very sharp peaks at the two general meetings. Now, in central-station practice, and in the work of a technical society, a more uniform load is very desirable. Such a more uniform load would be obtained for the American Electrochemical Society by the formation of local branches, with short, but more frequent, local meetings. The two general meetings would thereby lose nothing of their splendor, as they would remain the only meetings at which the electrochemists of the whole country would come together.

## APPLICATION OF THE ELECTROLYTIC DISSOCIATION THEORY TO MEDICINE AND BIOLOGY.

In the synopsis of our issue of last month reference was made to the growing abuse of the electrolytic dissociation theory, and of the teachings of physical chemistry by physicians in charge of mineral springs in Germany. It was pointed out that such abuse may bring the whole physical chemistry into disrepute. At least there is danger that this abuse may become so disgusting to true physicians and biologists that they will forget what the electrolytic dissociation theory has really accomplished for medicine and biology, and what it may be expected to accomplish in future.

It is therefore with great pleasure that we publish in this issue a paper by Dr. Bancroft on this very subject. One of the notable features of this paper is the conservative and truly scientific spirit in which the dissociation theory is dealt with. Its achievements are clearly pointed out, and with equal frankness it is stated where its assumptions fail. Further, the paper is an interesting proof of the almost unlimited field of the applications of electrochemical theories. One special point we may still mention: it is the pretty analogy with the large and small boy running together used by Dr. Bancroft for explaining how hydrochloric acid may get into the stomach. This analogy should be very useful for explaining to students the essential idea of Nernst's theories of diffusion and of concentration cells. It seems to us more important that a student should clearly grasp the fundamental idea of a theory by such a simple analogy than that he should go through a long series of mathematical deductions and formulas, as is generally done in this case, even in elementary text-books.

## REVOLVING ELECTRODES IN FACTORY AND LABORATORY.

A recent Chemical Society paper, by Dr. Edgar F. Smith, on an important departure from the usual procedure in electrochemical analysis by the direct precipitation of metals, shows a curious instance of a case in which the laboratory has lagged behind the factory. Nearly thirty years ago Wilde began the use of rotating electrodes in metal deposition, his purpose being to obtain a smooth deposit with higher current densities than could otherwise be used, and more recently Cowper-Coles has greatly developed the matter, determining the exact relation which exists between speed of rotation and current density. Other workers have not been idle, and the patents and literature contain numerous instances of work done under these conditions. A very interesting contribution to the literature on this subject is Mr. J. G. Zimmerman's Electrochemical Society paper, an abstract of which is given on one of the following pages.

Now it seems that it has been discovered that what operates well on a large scale in the factory will serve equally well on a small scale in the analytical laboratory, and that, by imparting a rapid movement of rotation to one or the other electrode, various metals may be separated in condition suitable for weighing and with great economy of time. We have long been taught, and truly, that the laboratory is the fountain-head of progress; that what are to-day the manipulations of the

scientific chemist may become to-morrow the methods of the manufacturer. But has the chemist ever adequately considered to what extent he might benefit by adopting for his own use the successful and carefully-elaborated methods of the factory?

## MR. CARNEGIE'S GIFT FOR A UNION ENGINEERING BUILDING.

For many years suggestions have been made to unite the official seats of the various national engineering societies in one and the same building in New York City. This building should at the same time contain all the libraries of the different societies, a large assembly hall for conventions, smaller halls for council and committee meetings and club rooms, with accommodations for the comfort of members visiting New York. These suggestions, although repeatedly made, were never carried into effect, the main reasons for the failure being a lack of enthusiastic harmony and the difference in the financial resources of the different societies. It was to be expected that in the present era of "trusts" the above scheme would again be taken up with greater engineering skill and greater energy. While we are going to press we are informed that the project is now approaching realization.

The Engineers' Club, which is a social organization of engineers in New York City, recently decided to build a new club house on Fortieth street, between Fifth and Sixth avenues. It is now proposed that the American Society of Mechanical Engineers, the American Society of Civil Engineers, the American Institute of Mining Engineers and the American Institute of Electrical Engineers shall unite with the Engineers' Club, and that a large Union Engineering Building shall be erected, running from Thirty-ninth to Fortieth street, between Fifth and Sixth avenues. The important factor which makes the realization of this plan possible and almost sure is the generous offer of $1,000,000 by Mr. Andrew Carnegie for the erection of this building. The lots for the building are to be bought by the various societies.

A meeting of representatives of different societies interested in this scheme was held on May 7th, and, while there was some discussion as to the best means of carrying out the project, there was a general harmony in the expressions of hearty accord with the general scheme. It may be that one of the national societies mentioned above, which has already a building of its own, may hesitate to join, but it is hoped that this society will leave aside its own individual preferences and will join with the others.

It is almost superfluous to point out what the realization of this scheme would mean. We may only mention the project to place all the libraries of the different societies, although in separate rooms, yet on one floor. What a magnificent general engineering library would thus be obtained. Moreover, the personal intercourse between engineers of various branches would bring about results the importance of which cannot be estimated at present. From the experience of the American Electrochemical Society, we know how many fruitful suggestions, thoughts and ideas an electrical engineer may get from his exchange of ideas with a chemist, or just as well a chemist from an electrical engineer. Should we not hope that the bringing together of all the great national societies in one Union Engineering Building should be equally, or even more, effective? We may briefly mention that the original plan is to have other engineering societies join with the large ones above mentioned in occupying the building. It may be doubted whether Mr. Carnegie ever donated a gift for a purpose more ideal and at the same time more promising than the building of a Union Engineering Building.

## ELECTRICAL ENDOSMOSE.

Since the classical investigations of Hittorf and Kohlrausch it has become customary to consider the electric conduction in an electrolyte as a mechanical problem, all the changes which go on in the solution being explained by migrations of ions. As far as this theory goes, it has been confirmed by various experiments. Now, in many investigations it is desirable or necessary to keep the anodic and cathodic departments separate. This is done by a diaphragm, and it has generally been assumed that such a diaphragm is inert and has no influence on the migration of the ions. We know that this assumption is wrong, because the phenomenon called electric "endosmose" is a well-established experimental fact. This is of theoretical as well as experimental importance.

In a paper of Hittorf, published last year, the author corrected some older values of his migration numbers, the error in his former determinations being due to special properties of the diaphragms used in his old tests. The discrepancies between experimental facts and the dissociation theory, pointed out by Mr. C. J. Reed in an American Electrochemical Society paper, read at Niagara Falls, may also be due to the phenomenon of endosmose. At the recent New York meeting Dr. Bancroft pointed out that in some cases the concentration changes due to endosmose is much larger than is generally assumed. He also pointed out that to a certain degree it is possible, by choice of the nature of the diaphragm, to regulate the endosmose at will. From this point of view the matter becomes of the greatest practical importance. The subject deserves the most careful experimental study, in view of the fact that we know very little about this phenomenon and that from a careful investigation we may expect very important results for theory as well as for practical applications.

The present situation is that, for certain practical electrolytic processes, diaphragms are required, and that the opinion has been prevalent that the only purpose of these diaphragms is to keep the compartments of the cell separate and prevent the mixing together of their contents. At the same time the diaphragms should not hinder the migration of the ions, which makes the required electrochemical action possible. The opinion has been prevalent that it is only necessary to use a diaphragm of sufficient mechanical strength and of low electric resistance, which is a somewhat inexact expression for the requirement that the joint resistance of the electrolytic paths through the pores of the diaphragm should be low. It had been silently assumed that the diaphragm itself does in no way influence the electrolytic action which goes on. But the phenomenon of electric endosmose proves that this view is wrong.

## FIFTH INTERNATIONAL CONGRESS FOR APPLIED CHEMISTRY, AND ANNUAL MEETING OF THE GERMAN BUNSEN SOCIETY.

The annual meeting of the German Bunsen Society will be held in Berlin, from June 2d to 8th, in connection with the Fifth International Congress for Applied Chemistry.

The following papers have been announced:

L. Ancel, Paris: On the Variations of Electric Resistance Under the Influence of Light, of Other Bodies than Selenium.

W. D. Bancroft, Ithaca: Experiments with Metallic Diaphragms—Constant Voltage and Constant-Current Separations.

G. Bodlaender, Braunschweig: On the Technical Application of Catalysis.

G. Bredig, Heidelberg: The Application of Electric Endosmosis and the Phenomena of the Colloidal Condition.

Desiré Corda, Paris: On Electromagnetic Separation of Minerals. Industrial Applications of Electrolytic Calcium.

A. Coehn, Goettingen: On Specific Metal Actions in Electrolytic Reduction and Oxidation.

K. Elbs, Giessen, and M. Buchner, Mannheim: On the Importance of Electrochemistry for Synthetic Organic Chemistry.

G. Erlwein, Berlin: On the Application of Electricity for the Utilization of Atmospheric Nitrogen.

F. Foerster, Dresden, and Brandeis, Aussig: On the Application of Electrolysis to the Preparation of Inorganic Compounds.

O. Froelich, Berlin: On a New Electric Resistance Furnace.

H. Gall, Paris: The Taking of Samples and Analysis in the Carbide and Acetylene Industries.

G. Gin, Paris: The Manufacture of Aluminium.

H. Goldschmidt, Christiania: On Reduction Methods.

H. Goldschmidt, Essen: The Manufacture of Steel in the Electric Furnace.

H. Grossmann, Muenster: On the Capability of the Rhodanion to Form Complex Compounds, as Compared with Halogen Anions and the Cyanion.

A. Guntz, Nancy: On the Preparation of Barium.

J. B. C. Kershaw, London: On Aluminium as an Electrical Conductor.

F. W. Kuester, Clansthal: Dissociation Pressure of Salt Solutions.

P. Lebeau, Paris: On Silicium Compounds.

M. Le Blanc, Karlsruhe: On Electrolysis with Alternating Currents.

G. Magnanini, Modena: On the Physical Chemistry of Wine.

W. Marckwald, Berlin: On Radio-active Substances.

P. Sabatier, Toulouse: On Catalysis.

H. Moissan, Paris: On Metallic Carbides.

W. Nernst, Goettingen: On Electrochemical Units. On the Determination of Vapor Densities at Very High Temperatures.

H. Nissenson, Stolberg, and H. Danneel, Breslau: The Quantitative Precipitation and Separation of Metals by Electrolysis.

F. Peters, Berlin: Storage Batteries without Lead.

P. Sabatier, Toulouse: On Catalysis.

Count Schwerin, Hoechst: On Practical Applications of Electric Endosmosis.

R. Schenk, Marburg: On the Dissociation of Carbonic Acid.

A. Sinding-Larsen, Fredriksvaern: Pseudo-molecular Compounds and Kryohydrates. Some Capillarity Phenomena and their Relation to Osmotic Pressure and Dissociation.

Edw. R. Taylor, Penn Yan: The Manufacture of Bisulphide of Carbon in the Electric Furnace.

J. H. Vogel, Berlin: Impurities in Commercial Acetylene.

E. Wedekind, Tuebingen: On the Chemical and Electrochemical Preparation of Zirconium and on Colloidal Zirconium.

C. Zengelis, Athens: On Chemical Reactions at Extremely High Temperatures.

## THE GIFT OF MR. ANDREW CARNEGIE FOR A UNION ENGINEERING BUILDING.

Mr. Andrew Carnegie has offered $1,000,000 to build a New York City home for the Engineers' Club of New York and for the following four national societies: The American Society of Mechanical Engineers, the American Society of Civil Engineers, the American Institute of Mining Engineers and the American Institute of Electrical Engineers.

The Engineers' Club has already purchased two lots for its building on Fortieth street, and, as Mr. Carnegie requires that the societies furnish the ground for the building, options have been obtained on five lots on the north side of Thirty-ninth street. Mr. Carnegie has advanced sufficient money to secure the options on the required property that must be purchased. The cost of the lots on Thirty-ninth street, to be bought by the four national societies, will be between $500,000 and $600,000.

None of the societies has so far been officially authorized to enter into the scheme. It is, however, certain that the electrical engineers and the mechanical engineers will accept the offer. The latter society had almost completed arrangements for a $350,000 building of its own, as its present quarters, on Thirty-first street, have been outgrown. The committee of the Institute of Electrical Engineers appointed to collect funds for a home of the society has declared itself enthusiastically in favor of the project. At the time we are going to press no exact information could be had concerning the attitude of the mining engineers and the civil engineers towards the scheme. The latter society has already a fine home.

An informal meeting of officers and prominent members of the various societies which are interested in the scheme was held on May 7th, and a joint committee, made up of three representatives of each of the societies, was arranged for, and it is probable that a meeting of this committee will shortly be held. It is readily understood that the official machinery of the various organizations does not permit of offhand acceptance of Mr. Carnegie's generous proposition.

## THE JOHN FRITZ MEDAL.

As is well known, the establishment of the John Fritz medal was signalized last year to celebrate the eightieth birthday of Mr. John Fritz, the fund collected for this purpose having been contributed by about 480 subscribers.

At Albany, N. Y., on April 18th, articles of incorporation of the John Fritz Medal Fund Corporation were filed with the Secretary of State. It is formed to collect and hold funds for a permanent investment, the proceeds of which will be used in the purchase of the gold medal to be known as the John Fritz medal, to be awarded annually to the person who shall be selected as having made the most notable scientific or industrial achievement during the period since the last award.

The medal is named to perpetuate the memory of John Fritz, Bethlehem, Pa., and the Board of Award is made up of members of the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers. The directors of the corporation are J. J. R. Croes, Alfred Noble, C. W. Hunt, E. E. Olcott, E. G. Spilsbury, James Douglas and C. Kirchhoff, of New York City; Robert Moore, of St. Louis; Gaetano Lanza, of Boston; John E. Sweet, of Syracuse; Robert W. Hunt, of Chicago; S. T. Wellman, of Cleveland; Arthur E. Kennelly, Cambridge, Mass.; Carl Hering, of Philadelphia; Charles P. Steinmetz, of Schenectady, and Charles F. Scott, of Pittsburg.

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The Gordon Battery Co. of New York have recently issued a booklet on the Gordon battery, giving some information regarding primary batteries in general, with illustrations and prices of the various sizes and types of the Gordon cell, besides the line of Gordon supplies.

## SOME APPLICATIONS OF THE ELECTROLYTIC DISSOCIATION THEORY TO MEDICINE AND BIOLOGY. *

By Wilder D. Bancroft.

If we dissolve a lump of sugar in water, we get a solution which does not conduct electricity, and which freezes at a lower temperature than pure water. The lowering of the freezing point depends on the concentration and the molecular weight of the sugar. If we dissolve a pinch of salt in water, we get a solution which conducts electricity, and which freezes at a lower temperature than pure water. The lowering of the freezing point is greater than we should expect from the concentration and molecular weight of the salt; in dilute solutions nearly twice as great. We account for the electrolytic conduction and the abnormal freezing point by assuming that salt dissociates to a certain extent in aqueous solution into electrically-charged sodium as ion, and electrically-charged chlorine as ion. An aqueous salt solution consists, therefore, of water, undissociated sodium chloride, sodium as ion and chlorine as ion. The electrolytic conductivity is due to the presence of the electrically-charged ions. With increasing dilution, the undissociated sodium chloride breaks up further into sodium as ion and chlorine as ion. Since solutions of other salts, of bases and of acids give abnormal freezing points and conduct electricity to a greater or lesser extent, we assume that these solutions are also dissociated into positive and negative ions, corresponding to the basic and acid radicals.

It may be asked whether this is all true. That is a question which no one can answer just now, and which is of no importance to us to-night. The electrolytic dissociation theory has proved useful as a working hypothesis, and has enabled us to predict a number of interesting facts. These facts will remain whether we continue to interpret them in the light of the dissociation theory or not.

Part of our assumption was that the ratio of undissociated salt to dissociated salt varied with the concentration, approaching zero for infinite dilution. The equilibrium will also be changed by adding either of the dissociation products. If we add a chloride to a solution of sodium chloride, we increase the concentration of chlorine as ion, and consequently the dissociation is forced back and more undissociated sodium chloride is formed. If the solution is already saturated with respect to sodium chloride, the excess of undissociated sodium chloride will separate as solid salt, and we have a case of decreased solubility. This can be shown very well by adding concentrated hydrochloric acid to a saturated barium chloride solution. The precipitate of barium chloride will dissolve on addition of water, and again be precipitated on addition of more hydrochloric acid.

Since the properties of a solution are the resultant of the properties of the components, we shall expect to find substances in the state of ions endowed with specific properties. This is the case, color being a striking instance of it. Dilute solutions of copper sulphate, nitrate, chloride and bromide are all blue, and we therefore postulate that copper as ion is blue. At higher concentrations these different salt solutions have different colors, presumably because of the color of the undissociated salt. In the same way most cobalt salts in aqueous solution are pink, owing to the presence of cobalt as ion; and most nickel salts green, owing to the presence of nickel as ion. It must be admitted that there are points not covered by the theory. The change of color with the dilution cannot be predicted quantitatively, and in benzene solutions we get the characteristic colors of the metals as ions, even though the solutions do not conduct electricity at all.

Coming back to dilute aqueous solutions, where the difficulties are least noticeable, we should expect that mixing two colored solutions would give us the color due to the single solutions if no special reaction takes place on mixing, and some other color if a reaction does take place. It is possible to make a cobalt salt solution and a nickel salt solution such that the pink and green are very nearly complementary. If we place these two solutions in plane-walled glass vessels and look through the two, we get the additive effect of the colors, any chemical action of one solution on the other being prevented by the separating glass walls. We can then mix these solutions, and we find experimentally that we get the same nearly colorless solution that we had previously obtained by superposition. If we try a similar experiment with a potassium cyanide solution and a copper sulphate solution, we get a different result. The color of the superposed solutions is blue. The mixed solution is colorless. From this we conclude that a reaction has taken place. On investigation we find that we have in the mixed solution the potassium salt of cuprocyanic acid, in which copper is part of the acid radical. Since copper is not present as ion, there is no reason that the solution should show the blue color of copper as ion.

Since certain solutions have a toxic action on certain plants or animals, it is not unreasonable to expect that in some cases the toxic action may be due to a certain ion. If we find that a certain metal as ion is toxic, while the undissociated salt is not, we should expect to get the greatest toxic action for a given concentration of metal when that metal is present in the form of a highly-dissociated salt. This has been found to be the case. A mercuric chloride or mercuric bromide solution is much more rapidly fatal to some forms of bacilli than a solution of mercuric cyanide containing the same amount of mercury per liter. The difference in the two cases is due to the fact that the concentration of mercury as ion is much less in the cyanide solution than in the chloride or bromide solution. Dreser has found that the action on fishes of mercury in the form of potassium mercuric thiosulphate is much less rapid than is the action of an equal amount of mercury in the form of chloride. With warm-blooded animals, such as the rabbit, no such difference was observed, presumably because the complex thiosulphate was decomposed rapidly. Kahlenberg and True found that seedlings of *Lupius albus* were killed by a concentration of 1.5 milligrams of copper per liter when the copper was present as sulphate, while they flourished in an alkaline sugar solution, even when the concentration of copper reached 160 milligrams per liter. It is not to be supposed from these instances that ions alone are toxic, and that the undissociated salt is always harmless. Kahlenberg and True found that in the case of mercuric cyanide both ions, and also the undissociated salt, are toxic to *Lupinus albus*. Clark found that undissociated chloracetic acid is more toxic to certain fungi than the dissociation products. Coupin has shown that potassium as ion is beneficial to Bordeaux wheat, and the use of potassium and sodium salts as fertilizers probably depends to some extent on the beneficial properties of certain ions.

On the other hand, it must be kept in mind that there are other factors to be taken into account besides that of electrolytic dissociation. The disinfecting power of carbolic acid solutions is increased by addition of sodium chloride, and decreased by addition of sodium acetate. The deciding factor here is what we call the chemical potential of the carbolic acid. Sodium chloride decreases the solubility of carbolic acid, increasing its chemical potential, and consequently its disinfecting power. Sodium acetate increases the solubility of carbolic acid, decreasing its chemical potential and its disinfecting power. Put in a general form, the properties of a substance are a function of the degree of saturation as well as of concentration. I lay especial stress on this because this is a point which has been pretty generally overlooked hitherto, and which is actually of great importance in many cases.

The cases considered so far have been cases of equilibrium, but we can find interesting instances of the usefulness of the dissociation theory in the field of reaction velocity. If we add an acid to a solution of cane sugar, we find that the sugar is changed gradually into a mixture of dextrose and levulose. This inversion, as it is called, takes place at different rates,

* A Lecture before the American Philosophical Society, March 20, 1903.

depending on the nature and concentration of the acid present, when the temperature and the initial concentration of the sugar are the same in all the experiments. On further investigation it was found that the rate of inversion varied very nearly, not absolutely, proportionally to the concentration of hydrogen as ion, as determined by other methods. It should be noted that, in terms of the electrolytic dissociation theory, any substance which yields hydrogen as ion in an aqueous solution is an acid by definition. This accelerating action of acids, or rather of hydrogen as ion, is not confined to the inversion of sugar. A very large number of reactions are accelerated in a similar manner. Since there is free hydrochloric acid in the human stomach, it occurred to Hoffmann that the rate of digestion might depend on the concentration of hydrogen as ion. To test this hypothesis he determined the rate at which a pepsin solution plus acid acted on albumen. With sulphuric acid there were irregularities, due to a special cause; but with the other acids the rate of digestion was approximately proportional to the concentration of hydrogen as ion. From this point of view, a substitution of acetic acid for hydrochloric acid in the stomach would be a very serious matter. Since the concentration of hydrogen as ion is 300 to 400 times as great in hydrochloric acid solutions as in equivalent acetic acid solutions, a meal that would be digested in three hours with the aid of hydrochloric acid would require three weeks or more with an equivalent quantity of acetic acid. In other words, after a real, old-fashioned Thanksgiving dinner we should begin to feel hungry again about Christmas time. Whether a glass of hydrochloric acid after dinner would be a good thing for a dyspeptic is a matter that lies within the province of the physician, and not of the physical chemist.

How the hydrochloric acid gets into the stomach is a question that may well interest the physical chemist. We eat salt, and it is changed into hydrochloric acid somewhere in and by the system. I asked a physiological chemist about this. He said that the salt gets into the blood, and that certain glands secrete hydrochloric acid back into the stomach, the alkali being neutralized by the carbonic acid in the blood. This explanation calls for a specific secreting power on the part of certain glands. It is interesting to note, however, that the physical chemist can get hydrochloric acid from salt without postulating a specific secreting power on the part of any of his apparatus. If we place a salt solution in a porous cup and stand the porous cup in water, there will be a diffusion of salt through the walls of the cup. Now, chlorine as ion tends to diffuse faster than sodium as ion, but is held back by the latter because of the electrostatic effects that would be caused if there were an excess of negatively-charged ions outside the cup and an excess of positively-charged ions inside the cup. The rate of diffusion of sodium chloride is therefore intermediate between the rates at which sodium as ion and chlorine as ion tends to diffuse. If a big boy keeps hold of his small brother's hand, the two will run faster than the little fellow alone, but not as fast as the big brother alone. Suppose we now add a weak acid to the salt solution, carbonic acid, lactic acid or acetic acid. It is necessary that equal amounts of positively and negatively-charged ions shall pass through the diaphragm at any moment, but that is the only restriction. Consequently we shall have the faster positive ion and the faster negative ion diffusing as one substance, leaving the slower pair behind. Hydrogen as ion tends to diffuse faster than any other known ion, and we therefore have hydrochloric acid diffusing from a mixture of sodium chloride and lactic or acetic acid, for instance. The porous cup is merely a dividing surface, and no specific properties are attributed to it. In view of the fact that secretion of hydrochloric acid might take place if the glands in question had no specific secreting power, we are justified in asking the physiological chemist to prove that these glands have a specific secreting power.

Another very interesting set of experiments has been carried on by Bredig, first in Ostwald's laboratory, at Leipzig, and later in his own laboratory at Heidelberg. The change of hydrogen dioxide into water and oxygen is accelerated by the presence of organic ferments, among others by blood corpuscles. The reaction is also accelerated by colloidal metals, platinum, silver, etc. For this reason these colloidal metals have been called inorganic ferments. This name would not be especially appropriate were it not for the fact that many substances have the same paralyzing effect, both on the blood corpuscles and on colloidal platinum. Thus prussic acid, mercuric chloride, hydrogen sulphide, hydroxylamine, cyanide of mercury, etc., all reduce greatly the accelerating action of platinum and of the red blood corpuscles on hydrogen peroxide. The parallelism is not absolute, however. It exists in about two-thirds of the cases thus far studied.

A most remarkable fact about these inorganic ferments is the dilution at which they work. The effect of colloidal platinum is noticeable when we have only one milligram of platinum suspended in 300 liters of water. In view of this, it no longer seems unreasonable that traces of arsenic in the thyroid gland should be essential to health, and the necessity for iron in the system is seen in a new light when we learn that iron salts exert a marked accelerating influence on many reactions involving oxidation.

Of great physiological importance is an entirely different class of phenomena, that involving a so-called semipermeable membrane. A semipermeable membrane is one which lets one of the components of a solution pass through, usually the water, and holds back the other. It is a membrane, in other words, which permits selective diffusion, or specific secretion if one so wishes. In view of the fact that many animal membranes are more or less semipermeable, it is quite possible that the secretion of the hydrochloric acid into the stomach may be due to a specific property of the glands.

When a solution is separated from the pure solvent by a membrane permeable to the solvent and impermeable to the solute, the solvent tends to pass through the membrane to dilute the solution. If this diffusion of the solvent is to be prevented, it is found that pressures of several atmospheres are necessary in dilute solutions, and that these pressures increase with increasing concentration of the solution. The membranes surrounding many plant cells are semipermeable, and the osmotic pressure of the contents, or the pull on the solvent, is about four and one-half atmospheres. This osmotic pressure is one of the important factors in determining the rise of sap in trees, capillarity being, of course, another factor. This pressure alone would cause sap to rise 140 to 150 feet, which is about as high as many of our trees grow. The corollary of this is that the cells of the California giant Sequoias must contain a more concentrated solution than those of our local plants. Unfortunately, no enthusiastic physical chemist has yet tested this hypothesis.

While the physical chemist is perfectly satisfied with the fact that the osmotic pressure in the plant cells is sufficient to account for the rise of the sap, the unfortunate botanist has to explain how the cells are formed. When you stop to think of it, the second row of cells presents difficulties. How did the salts for the second row get through the cells in the first row when these are impermeable to the salts by definition? The only answer possible is that the cells are not absolutely impermeable to the salts. The following experiment will show this. If we place a cut plant in a concentrated salt solution, the plant droops, because water flows out of the plant cells into the more concentrated solution. In time, however, the plant stiffens again, salt having diffused into the cell. This can be carried so far that salt crystallizes on the leaves of the plant. An animal which was in equilibrium with salt water would have to swell to ten times its bulk in fresh water if its cell walls were really impermeable. This diffusion of the protoplasmic salts has recently been shown experimentally in the case of *Limnæa stagnalis*.

In at least one instance a recognition of the osmotic relations

has been of great value in surgery. At one time surgeons used to wash out the abdominal cavity with water. This water was, of course, absorbed to some extent, causing the cell walls to become turgid, and then to burst. Now they wash out the cavity with a salt solution, of such strength that there is little or no tendency for water to pass in either direction. There is then no bleeding due to rupture of the cell walls. The "physiological saline salution," as it is called, should contain about 0.9 per cent. sodium chloride, in order to be in equilibrium with the cell walls. It is, as a matter of fact, a 0.6 per cent. solution. I have been told that this weaker solution is taken so as to be on the safe side in case of carelessness in making it up, the natural tendency being always to give full measure.

As the latest application of the electrolyte dissociation theory we have the work of Loeb and of Matthews on the stimulating action of certain substances as ions.

## ELECTROLYTIC PRODUCTION OF METALLIC COMPOUNDS.

A very important paper, which should be carefully studied by any electrochemist interested in this subject, was presented by PROF. C. F. BURGESS and MR. CARL HAMBUECHEN of the University of Wisconsin, at the recent New York meeting of the American Electrochemical Society. In the following we give an abstract of the paper:

The purpose of the paper is not to present an ideal or even an improved process for producing metallic compounds, but rather to point out the limitation of the methods at present available and to deal with some of the difficulties which must be encountered in large scale working.

Electrical energy suitably applied to a soluble sulphate, chloride, nitrate or similar salt of one of the alkali metals may produce a dissolving action upon a metal anode, with a consequent production of a salt of that metal similar to that which would be produced by ordinary chemical corrosion by a corresponding acid. It is from this fact that arises the commercial possibility of replacing acids commonly used by cheaper substances. Thus, in the production of metal sulphate or chloride, it is cheaper to obtain the $SO_4$ or Cl from a sodium salt than from the acid, especially in such localities where, by reason of freight rates or other circumstances, the acid may be of relatively high price.

A metal nitrate may be produced much more economically from sodium nitrate than from the nitric acid, as far as cost of materials is concerned. Figured on the basis of $NO_3$ content, 1.35 pounds of sodium nitrate is equivalent to 1 pound of nitric acid, and, at present market values, represents a relative cost of 2.7 cents and 8 cents. Similar relative values might be shown, in other cases.

Compensating for this saving in the cost of materials is the cost of power necessary in electrolytic operations, but where the process can be carried out on a large scale this cost can be made insignificant. The amount of energy necessary to decompose 1.35 pounds of sodium nitrate in the production of metal compound will be in the neighborhood of one-quarter horsepower hour, which, at a cost of .5 cent, makes the cost per pound about .15 cent. A further advantage for the electrolytic process is the possibility of recovery of valuable cathode products, one of which, in the case above considered, is .6 pound sodium hydroxide, representing a value considerably more than the cost of power.

To realize the advantages for electrolytic methods which such reasoning makes apparent requires suitable design of electrolytic apparatus. The necessary complications of such apparatus may, with justice, be urged as favoring the purely chemical methods, but as partially or even more than offsetting this disadvantage is the fact that from a given metal surface corrosion may usually be caused to take place with much greater rapidity through the aid of electric current than without. This produces economy of floor space and volume of apparatus.

The metal compounds which may be produced may be classified as soluble or insoluble, in accordance with the dissolving power of water for them. The chemical method for producing soluble metal compounds is typified in the action of an acid on a metal, either directly or indirectly; and the insoluble metal compounds may be produced from solutions of the former by precipitation by a carbonate, hydroxide or other precipitating agent. The double decomposition thus taking place results in the formation of a soluble salt as a by-product, which is usually of such a nature as to be difficult to recover in a pure state with an expenditure of energy sufficiently low to warrant it.

As compared with such chemical method, the advantages which can be obtained by the electrical current are the following: The dissolving acid and the precipitating base may be replaced by a cheaper salt, which is made by the electrical current to exert the dissolving action at the anode with the simultaneous formation of an alkali product at the cathode, and the subsequent union of these two products producing a precipitate with a regeneration of the original salt. This salt may be used over again, and does not represent a waste product. There is, therefore, no expensive material required to be consumed. While the electrical energy is a factor which must be taken into account, it is a comparatively unimportant one in figuring the cost of production on a large scale.

To the corrosion of lead and the production of various lead compounds much attention has been given from the electrochemical standpoint, due to the possibility of attaining the advantage of electrolytic over chemical methods in the greatest degree, and on account of the unlimited demand which exists for such products. Associated with the production of white lead is the record of many failures of electrolytic methods, and the older chemical methods still maintain control, in spite of various promises to the contrary.

One of the principal processes which has been employed for the production of a lead hydroxide is one in which the pig lead is used as the anode in a solution of sodium nitrate with a copper or other metal cathode. Faraday's laws tell us that for every ampère hour 3.8 grams of lead should be dissolved; 1.48 grams of sodium hydroxide should be formed at the cathode, and a mixture of these two products would form 4.45 grams of lead hydroxide with the regeneration of salt which was first decomposed. Assuming a current density of 20 ampères per square foot of anode surface, which is within the limits of possibility, the rate at which the lead will be removed or corroded is almost 80 grams per square foot per hour.

Unfortunately for practical operation, the process is far from being as simple as might at first sight be supposed. In the first place, the corrosion at the anode does not take place in an ideal manner; lead nitrate is not produced in such quantities as the application of Faraday's laws would indicate, and the discrepancy is accounted for by the formation of other basic lead compounds which are insoluble or only partially so. The formation of such undesired compounds may result in a waste of the lead, the introduction into the solution of impurities, the partial or complete insulation of the anode and consequent increase in the amount of power and the uneven corrosion of the metal which it is desired to transform.

In the case of sodium nitrate as the electrolyte, the reaction at the cathode is not simply the formation of sodium hydroxide and liberation of hydrogen. Sodium nitrate is reduced to nitrite, then through its lower forms, with the final production of ammonia. This resulting action causes the solution to become alkaline, and explains what at first sight might appear as a surprising fact, namely, that the current efficiency in the production of alkali is greater than 100 per cent.

For the production of lead hydroxide, by the mixing of the anode and cathode products within the cell, the following difficulty would then arise: The alkaline solution acting on the lead hydroxide, which has been precipitated, redissolves some

of it, forming a plumbate, and thus introducing lead as a soluble compound in the solution. The natural effect of a current passing through this compound is to deposit the lead upon the cathode, which is done in such a manner as to produce a loose, non-coherent, spongy mass of lead, which is easily detached, contaminates the product, decreases the efficiency and may even result in short-circuiting the cell.

Further, the production of nitrite at the cathode results, through the diffusion of this substance to the anode, in the formation of a nitrite of lead and basic lead compounds, which increases the difficulty of unsatisfactory corrosion of the anode. The production of ammonia, which, escaping into the air, may be a source of annoyance, also represents a waste material.

It will be self-evident, then, that the solution remaining after the cell has been in operation for some time is decidedly different in its chemical composition from that used at first.

To cause this electrolytic process to operate as is desired requires a design of the electrolyzing apparatus in such a way that the difficulty heretofore mentioned can be avoided or taken into account. It has been the purpose of some investigations which have been carried out in the laboratory of the authors to determine what these conditions are.

*The Anode.*—In order to bring the current efficiency of corrosion up to 100 per cent., with the formation of no secondary and undesirable products, careful attention must be given to various factors, such as the purity of the anode, its physical structure, current density, density and chemical nature of the electrolyte. The clean corrosion and 100 per cent. efficiency in lead nitrate formation can be attained by having a small amount of free acid in the neighborhood of the anode. The experience of the authors has shown that an acidity of 0.1 normal nitric acid will enable this satisfactory corrosion to be realized on lead plates carrying a current as high as 20 ampères per square foot. This characteristic of corrosion applies not only to lead, but to various other metals.

*Cathode.*—The reactions at the cathode should be carefully studied to determine qualitatively and quantitatively the reduction products there formed. The material should be such that no cathode corrosion can take place.

*The Electrolyte.*—This is the most important factor. It influences the character of the corrosion, the character of the primary and secondary electrolytic products, the amount of power necessary and the cost of keeping the solution in working condition. In the case of lead corrosion we are limited to the choice of such electrolytic materials as those whose anion produces, with lead, a soluble lead salt. This indicates the nitrates and acetates, among the cheaper materials, and the chlorides and chlorates, which are less satisfactory on account of higher resistance and lower degree of the solubility of resulting salts.

To overcome the difficulty of contaminating the precipitate with impurities formed at the anode, all that is needed is to draw the solutions from the electrolytic tank and, after having passed them through a filter, cause the precipitation to take place in another vessel. In the same manner, the dissolving action of the cathode solution on the resulting precipitate could be avoided by adding just enough of the cathode solution to cause complete precipitation of the anode products. To realize these conditions requires the complete separation of the two electrode products while in the electrolytic cell. This can be accomplished by means of diaphragms.

A single diaphragm will not serve in this process, as it would cause precipitation to take place within the diaphragm, and a consequent clogging of the same. To avoid such disadvantage, the electrode products may be kept completely separated by the use of two diaphragms. The stock solution feeding the cell is introduced between the two diaphragms, and the electrode solutions are drawn off from their respective compartments. Diffusion of the electrode solutions is prevented by maintaining a positive flow of solution through the diaphragms toward the electrodes at such a rate as to counteract any tendency for diffusion. To maintain a sufficient rate of flow requires a definite difference of pressure, which may be produced by maintaining the level in the various compartments at different heights. This method of separation has been described in United States patent No. 563,553, of A. B. Brown.

In the experience of the authors it was found that the maintaining of a proper difference of level involved a difficulty, because the density of the solution, which is at first the same in all three departments, changes during operation; it increases in the anode compartment and decreases, or remains practically the same, in the cathode compartment. The effect of the increase of density in the anode solution results in an equality of pressure toward the bottom of the cell, although there may be a difference of level at the surface of the solutions. This results in the diffusion of the anode solution into the intermediate, and thus into the cathode compartment. To obviate this an adjustment of the levels of the solutions to correspond with the relative density should be made. Another variable factor is the change of the character of the diaphragm, due to the influences of the solution and the chemical products upon the same. A light, firm canvas has been found to give very satisfactory results, but the alkaline cathode solution and the acidified anode solution act in different degrees upon the two diaphragms in changing the porosity and the rate of diffusion. Temperature and current density also influence this diffusion. The maintaining of a definite, fixed difference of level of solution between various compartments is hardly a satisfactory method of operation.

The authors have found that, by a very simple method, this difference of levels can be automatically adjusted by keeping the level of the solution in the intermediate compartment constant and drawing from the electrode compartments a certain definite *volume* of solution per unit of time. If the rate of diffusion with a given difference of level is not sufficient to supply this volume, the difference of level increases to such an extent that the flow through the diaphragm will be sufficient.

The fact that the lead solution in the anode has a higher density than the solution in any other of the compartments makes it necessary either to maintain very large difference in the level of the anode and the intermediate compartment, or the construction of the electrolytic cell with a limited depth. The authors have found that an anode plate about 8 inches in depth was the largest that could be used with the kinds of diaphragms described.

Anode compartments being limited in depth in the manner shown, and the width, by the construction of the cell and the diaphragm, to about 2 feet, and the anode current density being limited for reasons of satisfactory corrosion and economy of power, at about 10 ampères per square foot, the solution which should be drawn from every compartment is, in an hour's time, a comparatively small quantity. One liter per hour is a rate found desirable, and for a uniform flow of this amount requires a very small opening in the discharge tube. On account of the difficulty of entirely preventing the formation of insoluble particles in the solutions, these openings gave a great deal of trouble from clogging, requiring constant attention until another method of regulating the discharge was devised, which is shown in the adjoining figure.

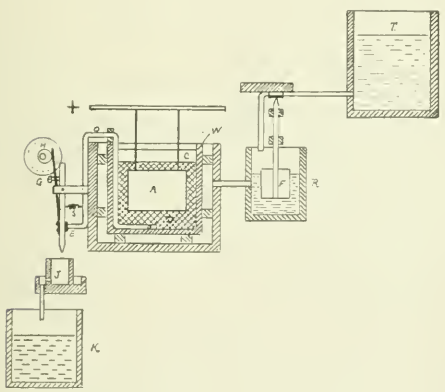
Instead of regulating the flow by the size of the opening of the siphon *o*, the opening is made large enough to allow any precipitated particles to readily pass through. This outlet, normally closed by a piece of rubber pressing against it by spring *s*, is opened periodically by an eccentric *H*, rotating at a fixed speed. The quantity of solution drawn off is regulated by adjusting the screw *G*. This method of regulation proved satisfactory, and may be advantageously used in various other electrolytic processes. It was found that in the operation of a solution of sodium nitrate, having a specific gravity of 1.12, 0.6 per cent. of free nitric acid was desirable to insure satisfactory anode corrosion. This free acid can be introduced either in the stock solution flowing between the two dia

phragms or directly into the anode solution. In the former method there is more uniform distribution of this acid than in the latter, but where the stock solution is acidified there is involved the disadvantage that more acid is required by some of it going into the cathode compartment, and thereby being neutralized. To overcome this disadvantage, a third diaphragm may be introduced, so that the stock solution is now supplied to two compartments, that flowing into one compartment being acidified to the proper amount and that flowing into the other being neutral.

The authors describe a small laboratory plant for the corrosion of lead. The electrolytic tank has three anode and four cathode compartments, and is capable of corroding about 10 pounds of lead per twenty-four hours. For the illustrations and diagrams representing the apparatus, the reader must be referred to the full paper, which will be presented in the Transactions of the Society.

By the method of the authors continuous operation can be effected with high percentage of corrosion, no clogging of diaphragms and uniformity of composition of solution running from the cell. The e. m. f. found necessary is about 1.4 volt, representing an expenditure of energy of 0.22 horse-power hour per pound of lead corroded.

Various methods of procedure may be followed in utilizing this apparatus for commercial purposes. A method of manufacturing white lead from such solutions, which has been extensively described in the literature, consists in mixing these two electrode solutions to form a lead hydroxide, and thereby a "regeneration of the original solution." The precipitate of lead hydroxide thus formed was treated by $CO_2$, either from the air or generated chemically, changing the precipitate to a lead carbonate, which is the useful white pigment. Analysis of the cathode solution, however, shows that the claim of "regenerating the original solution" cannot be realized, on account of the formation of ammonium and nitrite compounds. An analysis of the cathode solution on one run showed the following content per liter: 25. g NaOH, 3.52 g $NH_4OH$, 0.165 g $NaNo_2$, 54.3 g $NaNO_3$. A similar analysis of the anode solution showed a content per liter of 113.5 g Pb $(NO_3)_2$ and 57.6 g $NaNO_3$.




REGULATING THE DISCHARGE FROM ELECTROLYTIC APPARATUS.

The anode solution might be used to advantage for the manufacture of lead nitrate by fractional crystallization, but to do so requires the recovery of the values in the cathode solution, and it is upon this point that commercial success depends. By heating to a boiling temperature, the ammonia can be driven off and recovered, but the separation of the nitrite, the nitrate and the hydroxide cannot be readily accomplished.

In all methods for the production of metal compounds from a sodium nitrate electrolyte, the question of commercial success seems to depend upon the suitable treatment of the cathode solution, either by separating the materials or by finding uses for the solution as it comes from the electrolyzing tank. If the sodium nitrate fed into the electrolyzing tank could be completely utilized, the problem of the treatment of solutions could be considerably simplified. But, in order to keep the electrode products completely separated in the electrolyzer, it was found desirable to run the solutions at such a rate that about one-half the sodium nitrate passes through without undergoing electrolysis.

Some of the disadvantages attendant upon the use of sodium nitrate as the electrolyte material can be avoided by the use of sodium acetate. The amount of alkali produced at the cathode is equivalent to the lead acetate formed at the anode, and the chemical reactions are therefore simpler. The relative advantage of the acetate is, however, not determined by this factor alone. The cost of sodium acetate is much greater than the nitrate, calling for great care in the prevention of waste from leakage and washing the precipitate. The acetate requires to be used in a considerable degree of purity, while the ordinary commercial grade of sodium nitrate is sufficiently pure. The voltage necessary is considerably higher, and the difficulty of clean anode corrosion is decidedly against the acetate.

The experiments here described were carried out in an attempt to test on a laboratory scale various processes which have been described for the production of white lead. In this work, which was carried on for several months, the authors have found that it is entirely possible to produce a white lead in exactly the same composition, as far as the relative amount of hydroxide and carbonate of lead are concerned, as in the old Dutch process. The physical properties can also be duplicated. The conclusion seems to be justified, however, that there is little chance for the electrolytic process replacing the chemical methods for the production of this useful pigment, at least along the lines referred to. From the present market values of pure lead and the white lead made therefrom, it is seen that there is very little margin to pay the cost of the electrical energy, the necessary losses in the electrolyte, the cost of casting the lead into shape suitable for anode purposes, labor and depreciation of the electrolytic tanks and leave anything for a profit.

In the production of various other lead compounds, however, there seems to be greater opportunity for commercial application of the electrolytic method. The acetate of lead may be produced in a manner similar to that suggested for the production of the nitrate. Lead chloride may be produced from the electrolysis of a hot sodium chloride solution, lead chloride separating out on cooling. Lead chromate, which is a pigment used in large quantities, can be made by precipitating the anode solution by means of sodium bichromate, and thereby regenerating the original solution and furnishing the free acid necessary for the giving of uniform corrosion of the lead anode.

It will be noted that in all of the proposed processes for the electrolytic production of metallic compounds electricity plays only an incidental and sometimes very minor part in the operation. There are undoubtedly many places where the electrolytic step might be advantageously introduced into present purely chemical operations. Not only may the electrolytic effect of the current be utilized, but the heat effect may also be employed. A process for the production of metallic compounds utilizing the heat properties of the current consists in volatilizing the metal either in a resistance or arc furnace, and exposing the vapors or the fine metal particles thereby produced to the action of chemical nagents, which will produce the desired chemical compound. The controlling factor in this case is the cost of electrical energy, the amount of energy required to treat a pound of metal in this way being much greater than in the electrolytic methods.

## THE ELECTRODEPOSITION OF METALS ON ROTATING CATHODES.

At the New York meeting of the American Electrochemical Society a paper, by Mr. J. G. Zimmerman, was presented which should be of considerable interest from the practical standpoint. The author not only shows the possibility of nickel plating in one minute, instead of one hour, as is common practice, but he also shows that it is possible to deposit the nickel in such a manner that the subsequent buffing operation is avoided. It will be remembered that some time ago there was a considerable discussion in English journals as to whether the smoothness of the coating was due to centrifugal effect or to the friction of the solution. The present paper seems to show that it is due to the friction effect alone. In the following we give an abstract of Mr. Zimmerman's paper:

The use of high current densities in depositing metals is made possible by the use of rapidly-rotating cathodes, and an investigation of this subject has been carried out in the Applied Electrochemistry Laboratory of the University of Wisconsin. The method of investigation consisted of rotating a brass tube, 7/8 inch in diameter, attached directly to the shaft of a small electric motor, and in varying the speed, current density and composition of the electrolyte.

It was found that the rotation enables the current density to be run up to a very high value. At the comparatively low speed of 700 revolutions per minute and a current density of 200 ampères per square foot, a very good deposit of nickel, up to a thickness of about .04 inch, was produced. In the case of copper this thickness was increased to about .25 inch, and after that the cathode assumed a rough, pebbly appearance, the roughness increasing rapidly, until finally the higher elevations grew out in the form of trees, which pointed in a direction opposite to that of the rotation.

It was observed that the critical current density, *i. e.*, the current density at which a powdery deposit occurs, is approximately proportional to the speed of rotation. The highest speed which was used, however, was 2,500 revolutions per minute, corresponding to a velocity of 575 feet. The observations here made tend to confirm the statement of Mr. Cowper-Coles,* that if a peripheral velocity of 1,000 feet per minute and current density of 200 ampères per square foot be used, the copper will plate out with a high polish and to any thickness desired. The copper solution used was a nearly saturated solution of the sulphate with 10 per cent. of free sulphuric acid.

The depositing of nickel upon the rotating cathode revealed some interesting effects. While the ordinary current density used for nickel plating is about 6 ampères per square foot, it was found possible, at a rotation of 1,000 revolutions per minute, to run the current density as high as 300 ampères and still obtain excellent deposits of nickel. The ordinary double-nickel ammonium sulphate solution was used. When first used in the solution, the deposit was of a dull-white mat appearance. After operating the solution for some time, it was found that the deposit acquired a very high polish, comparable to that which is ordinarily obtained by means of a buffing wheel. From the fact that the anode failed to corrode in accordance with the amount of current, it was thought that this polished coating was the result of the solution becoming somewhat acid. By the addition of a small amount of free acid to the ordinary plating solution the character of the deposit was entirely ruined, and just what factors the polish depends upon has not been definitely determined.

It was found that it is possible to obtain a much thicker coating of nickel when the cathodes are rotated than when stationary, and, under suitable conditions, the deposition may proceed indefinitely without causing the metal to crack or break away from the surface. The increase of acidity, dilution and temperature of the electrolyte increases the tendency for the deposit to break up.

When portions of the deposited nickel became loose and curled away from the surface, they protected the space directly back of them from friction with the electrolyte, and as a consequence that part of the cathode received a dark, powdery deposit similar to the familiar "burned" appearance of nickel. On the other hand, the surfaces exposed to the friction of the solution were highly polished, and the unusual appearance of nickel trees was shown on the extreme edge.

The behavior of zinc is far different from that of nickel when deposited upon rotating electrodes. While it is difficult to obtain rough and tree-like deposits of nickel, it is very difficult to prevent them in the case of zinc. Zinc can be deposited in a smooth state only by adopting special precautions. One of these is to increase the friction of the solution against the metal through the aid of partition in the cell, which prevents the electrolyte from taking up a circulatory motion to correspond with the cathode. The closer the edge of this partition is brought to the cathode the smoother is the deposit. The tendency is for the zinc to be deposited in ridges, and the height and width of these ridges is inversely proportional to the amount of friction of the electrolyte. The solution which was used was a zinc-plating solution, such as is ordinarily used for electrogalvanizing, consisting of zinc and aluminium sulphate. It was found impossible to use as high a current density with a given speed of rotation as is possible with either copper or nickel.

Increase of current density was also shown to be possible in the deposition of iron, lead, antimony and silver.

* Jour of Inst. of Elect Eng., Vol. XXIX, 1900.

## INSULATING MATERIALS A FIELD FOR CHEMISTS.

In a paper with this title, read by Dr. Max von Reckling-hausen at the New York meeting of the American Electrochemical Society, the author points out how the development of electrical engineering has made possible the recent progress in industrial electrochemistry. The electrochemist is therefore under the greatest obligations to the electrical industry, and it is only fair that he should show his gratitude by helping the electrical engineer out of his troubles in a field where chemical research is of vital importance, *i. e.*, in the field of electrical insulating materials.

Chemists in general do not appreciate sufficiently the enormous value which chemical work in this field would have for the advance of the electrical industry. Moreover, they generally do not appreciate the different wants of the electrical engineer. It happens over and over again that chemists offer materials for insulation which may have one good property, but lack others, which may, for instance, have enormous insulating resistance to passage of current, but be so highly inflammable or so low melting as to be utterly useless for the purpose intended.

The author first classifies the important properties of insulating materials, as follows:

First. Electrical Properties.—(a) Insulation resistance or conductivity, expressed in ohms per cubic centimeter; (b) disruptive or dielectric strength, measured by the potential necessary to puncture the material; (c) dielectric constant, or specific inductive capacity, measured by the capacity in microfarads of a condenser having the particular material as dielectric separating the metal plates. This last-named property is less important than the two preceding.

Second. Mechanical Properties.—(a) Strength and workability (in case of solids); or (b) flexibility and workability (in case of semi-solids); or (c) viscosity (in case of liquids).

Third. Chemical Properties.—(a) Combustibility; (b) property of resisting the influence of moisture (hygroscopic quality), air, oil, acids, etc.

The factors which may considerably influence the properties of the insulating materials during use are the following: First, rise of temperature (sometimes going so far as to melt or char organic materials); second, mechanical stress, resulting

in change of shape or breaking; third, chemical action, as of water, oil, ozone, nitrous fumes (which may be generated by brush discharges near-by), or gases and fumes developed by factory processes in the neighborhood of the electrical apparatus.

Desirable qualities are, mainly, good insulation resistance, high disruptive strength and fair mechanical properties, especially workability. Undesirable are, mainly, combustibility and changes in the electrical and mechanical properties with rise of temperature or with age, and, of course, high price.

To chemically classify the insulating materials, it is practical to consider them under the headings of: I. Organic materials, liquid and solid. II. Mixtures of organic and inorganic materials. III. Inorganic materials.

*Liquid Organic Materials.*—These comprise the materials used mainly for transformer insulating and cooling, for condensers and more recently for circuit breakers. Such liquid insulators are the different oils and other liquid organic compounds. Most properties of the oils as used now are desirable. The worst feature inherent to them is their combustibility. The flash test and the viscosity test (and influence of long-continued use on the same) give a good idea of the usefulness of an oil for the purposes mentioned above. In the case of circuit breakers, as well as of transformers, where accidental high potential may have arced through the oil, the broken-down oil insulation should soon be repaired and the oil should come back to its original insulating power; at the same time it would be good that such oil does not develop too much of low-flash products, which bring with them the danger of fire. In circuit-breaker work some oils will break the arc off very sharply, with corresponding back effect on inductance in the line; others will be slower in their action, and may thus be more useful for such purposes. Naturally, one has to study the effect of the oils on the different materials they come in contact with. Fatty acids seem to be undesirable in such respects, because they are apt to react with copper.

To do away with the worst feature of oils, their combustibility, it has been proposed to use halogen carbon compounds instead of hydrocarbon compounds. It is distinctly worth investigating whether the products resulting from such liquids when the discharge goes through would be of too bad an effect on the apparatus. For instance, tetra-chloride of carbon would probably break up into carbon and free chlorine, and the latter would very likely injure the metal.

*Organic Compounds Used as Solids of More or Less Plastic State.*—Typical representatives of this long line are the different varnishes, lacquers, drying oils, rubber, compounds made from blood, glue, all the different cellulose materials, such as for textile fabrics, wood and mixtures of the different materials belonging to this group. It will be rather hard work to make material advance in this field by further research, as the makers of these materials are on the outlook for improvements for some time.

The author points out some of the disadvantages of the materials used nowadays. Many of them lose their mechanical strength and their insulating power and dielectric strength by age, and by short or long duration of high temperature and high electric stress. All of them are more or less inflammable. Here is probably the point where thorough chemical research could find its field. The pure cellulose compounds are probably very good in every regard, especially because they seem to be less affected by heat and less inflammable than the other materials of this group; but up to now they are fairly difficult to get into the desired dense mechanical shape. Nitro-cellulose and other celluloid compounds are ideal in this way, but, of course, are out of the question on account of their combustibility. New artificial masses, such as viscose, cellulose made out of cellulose solution in acids, metal salts, etc., and similar products may very well be worth experimenting with, because they are free from nitro-groups, and therefore are probably little affected by heat. Also glue and gelatine compounds, made insoluble by different methods, ought to be examined for their usefulness as insulators and, if necessary, chemically modified, so as to compete successfully, in properties and price, with materials used now.

One point is important for dynamo, and especially transformer insulation, *i. e.*, that the oil used should not have a dissolving or other injurious effect on the insulating material. Furthermore, the insulation should not be affected by moisture, which often in large amounts covers cold apparatus brought into warm rooms. Complaints are heard of attack of some varnishes on wires, particularly thin wires. For such purposes it may be good to prevent direct contact of the varnish and the metal by an intermediate coating.

Attempts are being made lately to produce asphalt compounds, which seem to have many excellent properties. Still, it will be fairly hard to find materials electrically and mechanically desirable but unaffected by oil and water. The author briefly refers to the old problem of finding a substitute for the expensive gutta percha.

*Mixtures of Organic and Inorganic Materials.*—Typical representatives of this group are materials made of asbestos or mica with varnish, rubber or paper, or similar materials out of the group mentioned before. The asbestos compounds, as a rule, lack high insulating power, also mechanical strength. The mica papers lack great flexibility and homogeneity.

*Inorganic Materials.*—The representative materials of this group are slate, marble, asbestos, porcelain and glass. They are, of course, practically unaffected by heat, but lack entirely flexibility, and are, furthermore, fairly expensive to form into the desired shapes. Better in the latter regard, but not so good insulators, are cement-like mixtures made out of water, glass and asbestos, or similar materials. Progress in this field may be expected in the line of the castable cements, although up to now they seem to be too hygroscopic.

That even the mineral insulators become conductors at high temperatures has been found out by people working on the Nernst lamp, where, after finding a good conductor at high temperature for the glower part, they had great trouble to find a good insulator, at high temperatures, for the heater part.

The main objection to marble for switchboard work is the great expense. Anything to replace marble would be of greatest importance. It should, of course, not be hygroscopic at all. Some time ago this was found to be important for high-tension line insulators, so that the makers were careful to make insulators absolutely non-hygroscopic by choosing glass free from alkali Still, the beneficial effect of this is, to a certain extent, overrated, as the heat developed by the leakage current is enough to remove the water which may condense on the insulator.

The paper is concluded by the remark that a tremendous step forward for the electrical engineer would be an insulating material of the flexibility of asbestos and the ideally high insulating and dielectric strength of mica.

## IONS AND ELECTRONS.

A paper on this highly interesting and timely subject was presented, by Dr. Louis A. Parsons, of the Johns Hopkins University, at the recent New York meeting of the American Electrochemical Society. In the following we give an abstract of this paper:

Soon after the construction of the first galvanic batteries water was decomposed into oxygen and hydrogen. Later Sir Humphrey Davy, with the great battery of the Royal Institution, decomposed soda and potash, both of which had been considered as elementary substances. And it was early found that whenever an electric current is passed through a solution of any acid, base or salt, decomposition occurs, and the elements or compounds formed appear at the electrodes. From this the idea was conceived of the dissociation or breaking down of the molecules of a substance into charged constituent parts. Faraday gave to these charged parts—atoms or groups of atoms—

the name of ions. According to the electrolytic dissociation theory—proposed by Clausius in 1856, and modified and given in its present form by Arrhenius—whenever a substance is dissolved a certain proportion of the molecules of the dissolved substance (depending on the concentration of the solution) are dissociated, so that the electromotive force acts as a directive force upon these dissociated ions, moving them in the direction of the oppositely-charged electrodes. Many recombinations and subsequent dissociations may occur in the passage to an electrode, and, as ions are removed from solution at the electrodes (by the formation of insoluble compounds), more molecules are dissociated, so that a sort of dynamical equilibrium is maintained.

The ratio of the mass of an ion to the electric charge carried by it is, according to Faraday's laws, a constant for any one substance, and is proportional to the chemical equivalent of that substance. Hence the charge carried by an ion is proportional to its valence. The charge carried by a hydrogen ion has been calculated to be of the order of $10^9$ electrostatic units ($10^{-10}$ coulombs).

The passage of electricity through gases at very low pressures gives rise to the cathode rays. These rays travel in straight lines; produce intense heating of solid objects against which they strike; cause fluorescence in many bodies acting as targets; are deflected by electrostic and by magnetic fields of force, and, when passed through metallic cylinders, induce electric charges on them. In short, they act exactly as theory shows negatively-charged particles, projected from the cathode with great velocities, would act. Upon the assumption that they were negatively-charged particles, J. J. Thomson calculated from the magnetic and electrostatic deflections (and also another method) both the velocity and the ratio of the mass of the carriers to their charge. The velocity came out different in different cases, but was of the order of one-tenth the velocity of light, while the ratio of $m$ to $e$ was the same in all cases, not being a function of the gas, as in the case of ordinary electrolysis, and was only about one-one thousandth as great as in the case of a hydrogen ion in electrolysis. By other experiments it was found that the charge $e$ was the same as the charge on a hydrogen ion in electrolysis. Hence the mass must be about one-one thousandth of the mass of a hydrogen atom. These small bodies concerned in all electrical discharges Thomson called *corpuscles*. In a tube giving cathode rays there are other rays, consisting of positively-charged bodies of the same mass as ions in electrolysis. These experiments suggested to Thomson that "negative electricity consists of the corpuscles . . . and that positive electrification consists in the absence of these corpuscles from ordinary atoms." This leads to a new theory, covering all electrical phenomena, including, of course, electrolysis. According to this theory, an uncharged atom or molecule is one having connected with it a corpuscle (or enough corpuscles to neutralize it). Ionization consists in the separation of the corpuscle from the atom. In gases at low pressure the negative ion is the corpuscle, the positive ion the atom or group of atoms, which have lost a corpuscle (or more). In solution the corpuscle does not remain free, but is attached to an otherwise neutral atom (or group of atoms).

Some, including Lord Kelvin and Oliver Lodge, have gone further than this, and suggested that the cathode rays are moving electric charges entirely divested of matter. These elementary charges—always negative—are, as it were, "atoms of electricity," and are known as *electrons*.

According to the electron theory, a neutral atom or molecule is one with "the neutralizing quantum of electrons," as Kelvin expresses it. Ionization is explained similarly to Thomson's explanations for corpuscles. The cathode rays consist of free electrons and the canal rays of atoms which have lost electrons. All electric conduction consists in the motion of electrons. In gases at low pressure we have what Lodge calls the "shot method"—the electrons are projected from the cathode like shot from a gun. In liquids and gases under pressure, the "bird-seed method," the electrons are attached to the atoms, and are, as it were, carried a short distance and then dropped. And in metals the "fire-bucket method," where the electrons are handed on from one atom to the next. Magnetism is explained by the motion of electrons, which take the place of the ampère currents.

A moving electron is surrounded by a magnetic field and an electrostatic field, and may be deflected by either one produced by an external source. When its motion is accelerated there is a radiation of energy through the ether. When the electron is abruptly stopped by a target, an electromagnetic pulse goes out through the ether with the velocity of light, and such pulses constitute the X rays. Centrifugal acceleration produces radiation also. If the electron is revolving in an orbit with constant speed, a continuous train of waves will be given out. These waves constitute ordinary light if the period of revolution of the electron is comprised within the limits of periods for the visible spectrum. There may be many electrons connected with a single atom or revolving inside the atom, each having its own period of vibration, thus producing many lines in the spectrum of an elementary substance. If a magnetic field is produced, so as to pass through the orbit of the electron, it will either accelerate or retard the speed. The doubling of the lines results, and the Zeeman effect is easily explained on this basis. The Aurora Borealis has been explained as due to the passage through our upper atmosphere of electrons, coming perhaps from the sun, following the lines of the earth's magnetic field.

All substances seem to spontaneously give off electrons, but some—the radioactive substances—give them off at a vastly greater rate than others. The emission of these electrons constitutes the Becquerel rays.

The mass of an electron (*i. e.*, its inertia) is, as has been said, about one-one thousandth of the mass of a hydrogen atom (about $10^{-26}$ gm). That is, it bears about the same relation to the mass of a gram weight as the gram does to the mass of the earth. The theory of the motion of an electrically-charged sphere gives for the value of the inertia of the electrification equal to two-thirds the square of the charge, divided by the radius of the sphere. It is interesting to calculate the diameter of an electron on the assumption that it is a sphere, and that this equation holds. Taking the best values, we find the radius of the electron to be between $10^{-13}$ and $10^{-12}$ centimeters. The radius of a hydrogen atom has been calculated to be about $10^{-8}$ centimeters. Hence the radius of an electron is one-ten thousandth or one-one hundred thousandth of that of an atom, or about the ten millionth or one hundred millionth part of a wave length of light. If dimensions were so magnified that a wave length of light would extend from Baltimore to New York, an electron would be about as large as a bullet or marble. Magnified the same, a foot-rule would cover the distance from the earth to the sun. If an atom were magnified until it were a globe 100 feet in diameter, an electron would be about the size of the dot on a letter *i* on a printed page.

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## J. WILLARD GIBBS.

J. Willard Gibbs, who died suddenly, of heart disease, at his residence, in New Haven, Conn., on April 28th, was born in New Haven, February 11, 1839. He entered Yale College in the autumn of 1854, receiving the A.B. degree in 1858 and the Ph.D. degree five years later, in 1863. Three years were spent in Europe in the study of physics, at Paris, Berlin and Heidelberg. In 1871 Dr. Gibbs was appointed professor of mathematical physics at Yale, and he held this chair until his death. An offer of a chair at the Johns Hopkins University was declined.

The published works of Professor Gibbs include:

Graphical Methods in the Thermodynamics of Fluids. Trans. Conn. Acad., Vol. II (1873).

A Method of Geometrical Representation of the Thermody-

namic Properties of Substances by Means of Surfaces. Trans. Conn. Acad., Vol. II (1873).

On the Equilibrium of Heterogeneous Substances. Trans. Conn. Acad., Vol III (1876-1878).

On the Vapor Densities of Peroxide of Nitrogen, Formic Acid, Acetic Acid and Perchloride of Phosphorus. *Am. Jour. Sci.* (3), Vol. XVIII (1879).

Two letters on Electrochemical Thermodynamics. Reports British Asso. Adv. Sci., 1886 and 1888.

Semi permeable Films and Osmotic Pressure. *Nature*, 1897, March 18th.

Notes on the Electromagnetic Theory of Light:

I. On Double Refraction and the Dispersion of Colors in Perfectly Transparent Media. *Am. Jour. Sci.* (3), Vol XXIII (1882).

II. On Double Refraction in Perfectly Transparent Media which Exhibit the Phenomena of Circular Polarization. *Am. Jour. Sci.* (3), Vol. XXIII (1882).

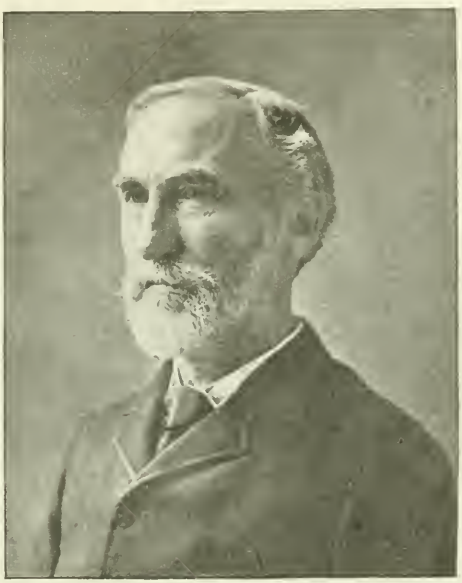
III. On the General Equations of Monochromatic Light in Media of Every Degree of Transparency. *Am. Jour. Sci.* (3), Vol. XXV (1883).

On the Velocity of Light as Determined by Foucault's Revolving Mirror. *Nature*, Vol. XXXIII, 582 (1885).

Elements of Vector Analysis, arranged for the use of students in physics. (Privately printed in 1881.)

Multiple Algebra. Proc. Am. Asso. Adv. Sci., 1886. (Address as vice-president of the Section for Mathematics and Astronomy.)

On the Determination of Elliptic Orbits from Three Complete Observations. Mem. Nat. Acad. Sci., Vol. IV.



J. Willard Gibbs

Letters to *Nature*, Vols XLIII and XLIV (1891); Vol. XLVIII (193), on Vector Analysis, Quaternions and the Ausdehnungslehre.

Elementary Principles in Statistical Mechanics. Yale Bi-centennial Publications.

Vector Analysis. Founded upon the lectures of J. Willard Gibbs. By E. B. Wilson. Yale Bi-centennial Publications.

Professor Gibbs was elected a member of the National Academy of Sciences (Washington) in 1879, associate fellow of the American Academy of Arts and Sciences (Boston) in 1880, foreign member of the Dutch Society of Sciences (Haarlem) in 1886; correspondent of the Royal Society of Sciences (Gottingen) in 1889; honorary member of the Cambridge Philosophical Society in 1891; honorary member of the London Mathematical Society in 1892; foreign member of the Royal Academy of Sciences (Amsterdam) in 1892; foreign member of the Royal Society (London) in 1897. Professor Gibbs received the honorary degree of Ph.D. from the University of Erlangen in 1893; of LL.D. from Williams College in the same year, and of LL.D. from Princeton College in 1896. In 1880 the Rumford medal was awarded to him by the American Academy of Arts and Sciences for researches in thermodynamics.

Personally, Mr Gibbs was a retiring, warm-hearted man, loved by all who were privileged to know him. He was always ready to furnish information to fellow workers, even when the appeals came from people whom he had never met, and even when the questions were in themselves foolish ones. I shall never forget the time and pains expended in making clear to me the errors into which I had fallen.

Dr. Gibbs was great as a pure mathematician, as a mathematical physicist and as a mathematical chemist. His work as a mathematician has received more immediate recognition and has had more positive influence than his work in chemistry, but it is probable that this is because he found a more intelligent audience among mathematicians than among chemists. Although the paper on "The Equilibrium of Heterogeneous Substances" was deemed worthy of the Rumford medal in 1880, two years after publication, this does not imply that the paper was understood then or now. It is not accessible as a separate publication in English to this day. A German translation has been made by Ostwald. Part of the paper has already been translated into French by Le Chatelier, and the balance is to appear shortly.

The attention of Roozeboom was called to Gibbs' paper by van der Waals, and what was condensed into a few paragraphs by Gibbs has been expanded into the phase rule by Roozeboom, and bids fair to become the basis of classification for the whole of chemical science.

The first general recognition of the importance to chemistry of this paper by Gibbs dates from the publication of the German translation by Ostwald, in 1892, and is due largely to Ostwald's enthusiastic statements in regard to the quality of Gibbs' work. While the fundamental importance of this paper is now generally recognized by chemists, it must be admitted that this is very largely lip service still. There is no man who pretends to understand Gibbs. There are some who have mastered small portions of this classical work, but that is all. As one distinguished scientific man has said, it is easier to discover a thing one self than to find it in Gibbs. This is perfectly true. But when one has, after much effort, discovered a thing, one finds it all in a more general form in Gibbs. The trouble is not that Gibbs is obscure. After one has mastered a small portion, one wonders that there should ever have been any difficulty in understanding that particular passage; but the difficulty reappears with the next passage. Gibbs' mind works along different lines from those of the chemist of to-day, and the latter cannot follow. We all know that Faraday's reasoning seemed obscure until Clerk-Maxwell put it into mathematical form. When some experimental chemist succeeds in doing for Gibbs mathematics what Clerk Maxwell did for Faraday's experiments, then for the first time shall we appreciate the real greatness of the man whose loss we mourn.

WILDER D. BANCROFT.

## NEW YORK MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The third general meeting of the American Electrochemical Society, held at New York City, from April 16th to 18th, scored the success which had been expected. The enthusiasm and good-fellowship of the members of the vigorous young Society—both the engineers and the scientists—have in no way abated. This is the most important point. On the other hand, for the success of the New York meeting as a social affair, not enough credit can be given to the untiring efforts of the local New York committee, with Dr. C. A. Doremus as chairman and Mr. Alois von Isakovics as secretary. The programme, as outlined in the last two numbers of Electrochemical Industry, was carried out successfully, and, to give due credit to whom credit is due, we may here quote the resolution offered by Dr. Bancroft at the end of the meeting and accepted unanimously: "That a hearty vote of thanks should be extended to the Chemists' Club, through whose hospitality our meeting has been made possible; to the German Liederkranz for throwing open the doors of its palatial club house; to our sister society, the American Institute of Electrical Engineers, for the pleasure given us of the joint meeting; to the various owners and superintendents of establishments and plants which we have been privileged to visit; to the local committee for its Herculean effort in our behalf. The magnificent results of their work have been visible to and appreciated by all of us, and we know what co-operation and organization must have been necessary to insure for us the most successful meeting of the Society."

### Business Meeting.

The meeting on April 16th was called to order by Dr. C. A. Doremus, chairman of the New York local committee. Dr. Wm. McMurtrie extended the hospitality of the Chemists' Club to the Society in some well-chosen words. He said that the Chemists' Club had been founded to become the center of the chemical activity of this country, and should be regarded as the headquarters of all chemists who visit New York. President J. W. Richards replied, and extended the thanks of the American Electrochemical Society to the Chemists' Club for the courtesies extended.

The official reports of the secretary and treasurer were then read. Mr. C. J. Reed, as secretary, reported that the Society has at present 492 members, and that this number will increase to 512 at the next election of new members by the Board of Directors. Mr. Reed also suggested that while it may still appear to be too early now to do anything towards the establishment of local branch organizations, yet at the present rate of increase of members such local branches may very soon become desirable, if not a necessity. Mr. Reed referred to the excellent results achieved by the American Institute of Electrical Engineers with this plan, and expressed the opinion that local branch organizations in the cities with a large membership list would be able to contribute materially to the value of the Transactions. Some kind of co-operation with European electrochemical societies was suggested, if possible, in such a way that the different societies supply the members of the other societies with their publications at a reduced rate.

From the report of the treasurer, Mr. P. G. Salom, it appears that the financial conditions are extremely good, in consideration of the comparatively very low membership fee.

The business meeting was then adjourned. It was again taken up in the Friday morning session, when the tellers, through Prof. G. W. Patterson, announced the results of the election of officers. The present constitution of the Board of Directors has not been changed: Dr. J. W. Richards was re-elected president; Mr. C. J. Reed, secretary; Mr. P. G. Salom, treasurer; Dr. W. D. Bancroft, Dr. C. A. Doremus and Dr. W. R. Whitney, vice-presidents, and Col. S. Reber, Dr. S. P. Sadtler and Mr. C. O. Mailloux, managers.

The vote in detail was as follows: For president—J. W. Richards, 160 votes; A. H. Cowles, 35; E. G. Acheson, 9; W. D. Bancroft, 5, and some scattered votes. For vice-president—W. D. Bancroft, 147; C. A. Doremus, 145; W. R. Whitney, 110; A. H. Cowles, 50; C. E. Acker, 27; Carl Hering, 19; E. G. Acheson, 18; C. F. Burgess, 17; C. S. Bradley, 11; C. P. Steinmetz, 10; R. M. Thompson, 8, and some scattered votes. For managers—S. Reber, 150; S. P. Sadtler, 137; C. O. Mailloux, 134; C. F. Burgess, 20; C. E. Acker, 18; C. P. Townsend, 16; F. B. Crocker, 15; W. D. Bancroft, 12; C. A. Doremus, 10; T. Wolcott, 10; F. J. Tone, 10. For secretary and treasurer, C. J. Reed and P. G. Salom received 210 and 204 votes respectively.

The president then announced the generous offer made by Mr. A. B. Frenzel, Denver, Colo., who proposes the award of $250 for the best paper on the treatment of rare metals, such as molybdenum, vanadium, thorium, tungsten, etc. Mr. Frenzel, whose offer was accepted by the Board of Directors, will supply engineers who intend to take up this problem with any reasonable amount of ore necessary for the investigation, f. o. b. Denver. The award of the prize will be made by the Board of Directors of the Society.

The number of members and guests who registered at the meeting was 260. An alphabetical list of all who registered is found on another page of this issue. Among the foreign guests of the Society were Dr. Walter Nernst, the famous professor of electrochemistry of Goettingen, Germany; Dr. Bussmann, superintendent of the Nernst lamp department of the Allgemeine Elektricitäts Gesellschaft, Berlin, Germany; Dr. A. Franke, director of the Siemens & Halske Co., Berlin, Germany, and Dr. Reisnegger, chemist of Meister, Lucius & Bruening, Augsburg, Germany.

The morning and afternoon of Thursday, the morning of Friday and the morning of Saturday were devoted to the reading and discussion of papers, a full report of which will be found below. For the afternoons of Friday and Saturday visits to places of interest had been arranged, the list including the works of the Sawyer-Man Electric Co., a special exhibit of electrochemical apparatus by Eimer & Amend, the laboratories of the Cooper Union Institute, the Willyoung & Gibson Co., the Crocker-Wheeler Electric Works, a galvanizing plant installed at the Brooklyn Navy Yard by the United States Electro-Galvanizing Co., the Edison station at Thirty-eighth street, the Manhattan Railway Co's power house at Seventy-fourth street, the Metropolitan Street Railway Co's power house at Ninety-sixth street, the new Rapid Transit Tunnel at Fifty-ninth street and Broadway, Columbia College and the New Jersey Zinc Works.

On the evening of Thursday a reception and a subscription banquet was held in the handsomely decorated hall of the German Liederkranz Society. It proved to be the most notable social feature of the convention. The after-dinner speeches were greatly enjoyed. Dr. C. A. Doremus acted as toastmaster, and the following toasts were responded to: "America, the Electrochemical Center of the World," by Dr. J. W. Richards; "Development of Electrochemical Theories," by Dr. Walter Nernst; "The American Institute of Electrical Engineers," by Mr. C. F. Scott, president of the American Institute of Electrical Engineers; "The American Chemical Society, by Dr. C. F. Chandler, of Columbia University, and "Kitchen Chemistry," by Dr. H. W. Wiley, chief of the United States Department of Agriculture. Mrs. Anna Eisen, soprano, and Mr. Carl Schlegel, baritone, received much applause for several songs, Dr. G. Drobegg accompanying them with much art on the piano.

On Friday evening a joint meeting of the American Electrochemical Society and the American Institute of Electrical Engineers was held in the chapel of the College of the City of New York. President Scott, of the Institute, made some introductory remarks, and then Mr. Hammer read an excellent paper, an account of which will be found below.

On Saturday evening Dr. J. W. Richards delivered his excellent presidential address, a long abstract of which will be found elsewhere in this issue. Afterwards Mr. P. H. Thomas exhibited the Cooper-Hewitt rectifier. Alternating current

was converted by its means to direct current for lighting lamps and running a direct-current motor. Dr. M. von Recklinghausen then exhibited the Cooper Hewitt mercury lamp, and dealt especially with the actinic properties of the light. Some photographs of groups of members and guests, taken with the Cooper-Hewitt light after Dr. von Recklinghausen's lecture, are reproduced below. The official programme was then concluded by a German-American smoker ("Kneipe"), which was greatly enjoyed. Dr. Richards spoke of his college days in Heidelberg and Freiberg, and Dr. McMurtrie, Dr. Doremus, Dr. Keith and others told many entertaining stories. The affair was indeed so enjoyable that, after the smoker was over, most of the members present concluded that it was still too early to adjourn *sine die*, and started another unofficial session in the hospitable hall of the Liederkranz.

A complete report of the papers and discussions is given below.

Constant Voltage and Constant-Current Separations.

The paper by Dr. W. D. Bancroft, of Cornell, on this subject had for its purpose the establishment of a general rule of classification for the numerous methods given in text-books on electro-analysis. There are used in electro-analytical practice two essentially different methods for separating metals from other metals. In one method the voltage is kept constant, in the other the current. Dr. Bancroft showed the conditions which determine whether the one or the other method is to be used.

Since the electrolytic separation of two metals depends on the fact that one precipitates at a lower voltage than the other, it would seem as though the proper way to effect a separation is to hold the voltage at a value high enough to precipitate the one metal, but too low for the precipitation of the other metal. By using this method the current gradually decreases, and drops to a very low value as soon as the first metal is completely precipitated, thus giving an automatic indication of the degree of precipitation.

As a matter of fact, however, this constant-voltage method is not used in most of the standard separations, which are rather to be classed as constant-current separations, even though the current may not be absolutely constant. In such a constant-current method something which does not change the results, but not the second metal, must be deposited, together with the first metal. It is evident that if hydrogen is developed it does not change the results. Therefore, if the decomposition voltage for hydrogen in the solution is below the decomposition voltage of one of the two metals, then a constant-current separation becomes possible. In electro-analytic work in former years no voltmeter was generally used in the circuit, and this is the reason why all except some of the most recent separations are constant current separations.

To apply these principles, Dr. Bancroft has collected the data of former experimenters, and has put them together in tabulated form. Dr. Bancroft gives tables in which the metals and hydrogen are arranged according to the value of their deposition voltage from various solutions. This order is different for different solutions. Tables are given for the sulphates, nitrates and chlorides; cyanides; oxalates; phosphates and tartrates. A second set of tables gives a summary

PHOTOGRAPH TAKEN DURING FRIDAY'S SESSION.

of the majority of the separations for silver, mercury, copper, bismuth, tin, lead, nickel, iron, cadmium and zinc. Dr. Bancroft's rule of classification of the different methods is that if hydrogen is evolved before the second metal, the constant current method is feasible and is used in practice, otherwise constant voltage must be used. The tables given by Dr. Bancroft's paper show that the rule is generally correct, although there are two or three exceptions, explanations of which are suggested by the author. In general it may be said that the overwhelming majority of the usual electro-analytical separations can be run at constant current without reference to the voltage.

The paper was discussed by Messrs. Bigelow, Carhart, Hering, Keith and Reed. Attention was called to the essential differences between the separation of metals for analytical purposes and the separation of metals in industrial electrometallurgy. In the latter case soluble anodes are often used, which are, of course, not suitable for analytic work. Concerning the

electrolytic deposition of brass, Dr. Bancroft expressed his doubts whether brass is really deposited. It seems that when copper and zinc are deposited simultaneously the deposit may look like brass, but the separate particles of zinc and copper can be distinguished by the microscope.

### Experimental Study of Some Electrode Effects.

A paper on this subject by Dr. H. T. Barnes, of McGill University, Montreal, Canada, was read, in the absence of the author, by Dr. Bancroft. The author remarked that platinum electrodes under apparently the same conditions do not behave alike. There is generally found a potential difference between two platinum electrodes in a solution. He shows that this is due to the presence of air, which is dissolved in the solution. This is even more important than any air dissolved in the electrodes. When the solution is freed from air, the anomalies disappear. The paper was not discussed.

### The Electrolysis of Water.

A paper on this subject was presented by Dr. J. W. Richards, of Lehigh University, and Mr. W. S. Landis. The authors gave an account of a long series of experiments, in which they investigated the various problems connected with the electrolysis of water from various points of view. A most interesting experiment was made with a closed vessel, consisting of a very strong thermometer tube. It was completely filled with dilute sulphuric acid, care being taken to get rid of dissolved gases by means of boiling. Platinum wires were introduced through the ends, so that the distance between their ends was about 1 mm. The ends of the tube were most carefully sealed with Canada balsam. Under these conditions the authors found that no current would pass, even with an applied e. m. f. of 3.3 volts. As soon as the seal at one end was broken so that air had access, current was found to pass at once. In this experiment the tube was strong enough to stand a pressure of about 5,000 atmospheres, while the evolution of gas by electrolytic action would produce a pressure of 1,800 atmospheres only.

J. W. Richards.

Another set of experiments was made, in order to test Thomson's rule in an interesting manner. The Joulean heat developed during electrolysis was determined from the rise of temperature by means of a thermometer; at the same time the e. m. f. and current were carefully measured. From the difference thus experimentally established between the heat developed and the electrical energy consumed, it was found that the decomposition voltage of water is 1.49, in accordance with Thomson's rule.

The authors arrived at the same result in an entirely different method by observing the cathode under the microscope, while the applied e. m. f. was gradually changed in steps of 0.05 volt. At 1.40, 1.45 volts no gas bubbles could be observed, while they appeared at once at 1.5 volts or above.

The authors have also made an extended study of the residuary current, or, as the Germans call it, Reststrom. Their results confirm the opinion already expressed by Helmholtz, that the gases dissolved in the electrolyte play a very important part in this phenomenon. They found that current passes with any applied e. m. f. below the proper decomposition voltage, the amount of current increasing with the voltage. The concentration of the sulphuric acid used makes very little difference, but the amount of the current depends largely upon the quantity of the gases dissolved in the electrolyte. These gases act somewhat like depolarizers. The authors further made experiments with the electrodes 8¾ meters apart, and in another case a small fraction of a millimeter apart. In the first case there was absolute conformity with Ohm's law, as in metallic conduction, but not in the latter case. The authors also give some notes on the work of Danneel and Bigelow on the same subject.

There was an animated discussion, in which Messrs. Bancroft, Bigelow, Burgess, Cowles, Hering, MacNutt and Reed participated. Mr. Hering doubted the suitability of platinum as electrode material for such experiments, because it combines with hydrogen and oxygen. From experiments made by him, he preferred gold electrodes. Mr. Reed called attention to an experiment made long ago by Faraday, who drew from it the conclusion that if the applied e. m. f. is above a certain value there is electrochemical action, while below this value there is metallic conduction. Professor Burgess described an experiment made by him on the influence of the pressure upon the e. m. f. He used a strong cylinder of steel, filled with a dilute acid solution, and could pass a current with an e. m. f. of less than 1 volt. The current decreased rapidly, but rose again to its former value on shaking the cylinder. Dr. Bancroft made some critical remarks on the statements of the authors on the validity of Ohm's law, and expressed his belief that the experiments could not be considered accurate enough to prove the absolute exactness of Thomson's rule in this case. We have absolute evidence that this rule is, in general, not exact.

### Experiments with Metallic Diaphragms.

Dr. W. D. Bancroft pointed out in a paper on this subject that when we interpose a metallic plate between anode and cathode there may pass no current through it, or all the current may pass through it, or any part of the current. Instances of the case when all the current passes through the diaphragm are the mercury in the Castner soda process, and the copper electrodes in the Hayden system of copper refining in the Baltimore works. Instances of metallic diaphragms through which no current passes are the iron-gauze diaphragms in the Castner sodium process and the diaphragms in the Siemens & Halske process for hydrogen and oxygen.

When the diaphragm fills the cross section of the cell completely, all the current must pass through it, if there is any current at all. If the diaphragm is a completely reversible electrode (*i. e.*, if the cathodic electrochemical reaction on one side of the diaphragm is the exact reverse of the anodic reaction on the other side), no extra e. m. f. is required to pass the current through it. If it is not reversible, or only partially reversible, an extra e. m. f. is required to pass the current through, and this e. m. f. is equal to the value of polarization.

If the diaphragm does not fill the cross section completely, no current will flow through it, unless this requires a smaller expenditure of energy than to make the current flow through the electrolyte. Since the resistance of a metal plate is practically always less than the resistance of an equal thickness of electrolyte, current will always pass through an interposed plate, unless prevented by polarization.

If a thick carbon plate is interposed between anode and cathode in a copper sulphate solution, so as to fill partially the cross section, then, when the fall of potential between the ends of the carbon plate, as measured on copper wires dipped in the electrolyte, is less than 1 volt, there is no precipitation of copper. When the fall of potential exceeds 1.4 volts, there is a rapid precipitation of copper on the end of the carbon plate nearest the copper anode.

Dr. Bancroft then wanted to make the same experiments with platinum, instead of carbon, and, as a platinum plate of great thickness would have been extremely expensive, he

thought the following arrangement would be equivalent: He placed two movable platinum electrodes in the electrolyte, and connected them outside by a platinum wire. But he found that this was not equivalent to a massive platinum bar. Instead of one electrode being anode and the other cathode, each electrode behaved to a certain extent both as anode and as cathode. The author explains this by means of diagrams, and points to a depolarization phenomenon which here occurs, with the consequent precipitation of copper under differences of potential far below the normal decomposition voltage for the solution. He calls attention to the importance of determining the exact conditions under which decomposition takes place with the minimum voltage, in order to avoid those conditions, for instance, in the electrolytic generation of hydrogen and oxygen when using an iron-gauze diaphragm. The paper was not discussed.

## THURSDAY AFTERNOON SESSION.

### THE PROTECTIVE ACTION OF ZINC CHLORIDE ON METALLIC IRON.

The first paper of the afternoon session was read by MR. C. J. REED. The rusting or oxidation of metallic iron in the presence of water and saline solutions is now recognized to be an electrochemical process, in which the water or saline solution is the electrolyte, the metallic iron the anode and small particles of impurities in the iron, like graphitic carbon, etc., are the cathode. This combination evidently represents a short-circuited cell, and the iron is attacked. Now, Mr. Reed argues that this attack of iron in a chloride solution would be due to the chlorine ions, and should take place in a zinc chloride solution in the same manner as in a sodium chloride solution. On the other hand, he found that iron nails placed in a zinc chloride solution for two years did not rust in any case. In strong zinc chloride solutions, which had been boiled with metallic zinc and contained no free acid, there was not the slightest action of any kind upon the iron. He asked the adherents of the electrolytic dissociation theory to explain this. The discussion of the paper was very brief

C. J. REED.

### INSULATION MATERIALS, A FIELD FOR CHEMISTS.

The next paper was read by DR. M. VON RECKLINGHAUSEN on this subject. A long abstract of this paper will be found on another page of this issue. The paper was not discussed.

### A HISTORICAL REVIEW OF THE STORAGE BATTERY.

A paper on this subject was read by MR. H. B. COHO. It was a concise and probably complete record of the various phases of the development of the storage battery industry, and of the gradually-extended commercial applications of the storage battery. In view of the fact that the paper was itself a concise *résumé* of an historical development, it is impossible to review it briefly. In the discussion which followed Prof. H. S. Carhart said that in 1881 Plante told him he had tried applying by mechanical means the active material on the lead plates (which was later patented by Faure and Brush), but had found such plates inferior to formed plates. Dr. N. S. Keith stated that, in 1881, he himself had devised a plate which did not require forming.

### THE USE OF PARAXYLINE IN ELECTRIC STORAGE BATTERIES.

Another paper on the subject of the electric storage battery was presented by MR. ELMER A. SPERRY. In the first part of the paper the author dealt with the inherent weakness of the positive plate of a storage battery. In practice its life is always found to be shorter than that of the negative plate. The reason is that the particles of the positive plate tend to drop off, on account of expansion and extraction, due to the chemical changes during operation. Moreover, in automobile batteries this tendency of the particles of the positive plate to fall off is increased by the surface wash of the electrolyte. When these particles are allowed to drop off and fall to the bottom of the cell, not only the capacity of the plate is diminished, but there is also the danger of a short-circuit between the positive and negative plates. For all these reasons, it has been found advantageous to cover the positive plate with an envelope to hold the active mass firmly in place. Planté has already made experiments in this line.

Mr. Sperry has developed the pyroxyline envelope, which is made of open-mesh cotton cloth, such as "cheese cloth," carefully freed from water and starch, and chemically treated to form a cellulose nitrate, called "pyroxyline." The addition of a small amount of nitrobenzol in the final washing makes it inert. When dry it is highly inflammable, but not when wet; this was demonstrated by experiments. (The method of winding this pyroxyline envelope around the positive plate was described and illustrated in ELECTROCHEMICAL INDUSTRY, Vol. I, page 149, December, 1902.)

Some questions raised by Mr. C. J. Reed in the discussion elicited the answer by Mr. Sperry that the initial difficulties which were experienced in the manufacture of this envelope have now been entirely overcome, and that batteries with such envelopes have been in continued use for about three years. The pyroxyline envelope cannot be used for the negative plate

### THE CONCENTRATION CHANGES IN THE ELECTROLYSIS OF BRINE.

A paper on this subject was read by DR. W. H. WALKER, who took issue with some theoretical opinions expressed by Mr. C. P. Townsend in ELECTROCHEMICAL INDUSTRY, December, 1902, Vol. I, page 119, concerning the increase of the undecomposed sodium chloride concentration in the caustic soda department of a cell for the electrolysis of sodium chloride. Dr. Walker showed how this increase of concentration may be easily explained by the theory of migration of ions, if Hittorf's transport numbers are properly taken into account. At the beginning of the electrolysis only the sodium ions and chlorine ions travel. Afterwards, when sodium hydroxide has been formed, the HO participates in the transmission of the current, so that now both hydroxyl and chlorine ions travel in the direction from the cathode to the anode. This fact complicates somewhat the mathematical theory of the phenomenon, which, however, has been worked out by the author and found to agree with the experimental facts. A diagram was exhibited by the author which illustrated the migration of the ions very clearly, and in another diagram the results of tests were given in curves.

In the discussion Mr. C. P. Townsend and Mr. P. Fireman participated. It was pointed out that the cell to which Mr. Townsend referred in his former article was of special construction, different from that assumed in Dr. Walker's paper. Mr. Townsend stated, however, that, on account of the patent situation, he is not at liberty at present to discuss the whole matter freely, but will do so in future.

### THERMO-ELECTRIC FORCE WITHOUT DIFFERENCE OF TEMPERATURE.

DR. HENRY S. CARHART then presented an interesting theoretical paper on this subject, a rather full abstract of which is given on another page of this issue. It was discussed by Messrs. Cowles and Richards. The question was raised as to why the law that in a closed circuit of metals the sum of all the thermo-electromotive forces at the junctions is zero should not also be valid if there are electrolytes in the circuit. Dr. Carhart replied that there is no reason whatever for such a supposition, because the

two cases are fundamentally different. In the case of a closed circuit of metals the assumption that the sum of the thermo-e. m. f's would not be zero would lead to a contradiction with the well-established laws of thermo dynamics. This is not the case when there are electrolytes in the circuit.

### Corrosion of Metals by Electrolysis.

The last paper of the afternoon session was presented by Mr. A. A. Knudson, who gave a summary of a long series of observations and tests made in connection with electrolytic corrosion. After some introductory remarks on the influence of earth currents on telephone and telegraph lines, he discussed the copper plating of iron ships. Should such construction of vessels come to be used, the principal point is to keep the plating intact, free from punctures or abrasions, the hull closely examined when in dry dock, and exposed places upon the iron replated with a plant which may be carried on board or kept at the dock. The worst thing to do when repairs become necessary would be to put iron patches over the copper-plated hull, as in this case corrosion is bound to follow. A still more important case of sea-water corrosion, due to placing together dissimilar metals, is sometimes found on the propeller shafts of steamers. After a careful consideration of the subject, he concludes it would be the proper thing, when seeking improvements, to abandon the method of attaching brass or bronze

W. D. Bancroft. C. A. Doremus. H. S. Carhart. C. Hering.
P. G. Salom. J. W. Richards. C. M. Hall.

bearings to steel shafts. Concerning the corrosion of bridges, he points out the importance of occasional examinations. If there should be danger, a simple remedy to prevent excessive corrosion would be to keep the iron work well painted, caulk the seams between the iron and wooden planks with oakum and pitch or paint the seams over. The author then discussed at length the electrolytic corrosion of gas and water pipes, and in general the underground metallic structures by the return currents of trolley systems. He gave a summary of numerous tests made in this respect in New York and Brooklyn, especially in connection with the Kent avenue power house. In these tests the way of the return currents was carefully traced. The author concludes that "the *future* possibilities of damage by electrolysis, due to railway currents upon valuable underground structures, as well as those shown to be going on at the present time, should cause grave concern if the electrical conditions as they at present exist are to be continued." The only complete solution of the difficulty would be the adoption of insulated returns by the traction companies, either in form of the conduit system or the double-trolley overhead system.

The paper was discussed at length, notably by Mr. Carl Hering, who pointed out that the measurement of potential differences, as in common use in connection with the problem of the stray currents from the rails used as return, is essentially wrong. What is of importance for the electrolytic corrosion of gas and water pipes is the current which flows in them and passes from them at a special point into the earth. Measurements of e. m. f. do not indicate accurately the current which flows, because the resistance is also a very important factor which determines the current. To find the current which flows in a pipe, Mr. Hering suggests the following method, illustrated in the adjoining diagram: Connect two points of the pipe with a voltmeter V and take the reading $e_1$, which, according to Ohm's law, is R1, if R is the resistance of the pipe between the two points and I the current in the pipe. Then connect the same two points of the pipe also to an ammeter A and take the readings $e_2$ of the voltmeter and $i$ of the ammeter. In this case the current $i$ flows through the ammeter circuit, so that the current in the pipe is only I — i; hence Ohm's law gives $e_2 = R(I - i)$. From this and the first equation, $e_1 = RI$, it follows at once that the current I in the pipe is $I = \frac{i\, e_1}{e_1 - e_2}$. This is therefore a simple method for determining the current in the pipe by means of an ammeter and a voltmeter. At such points of a pipe where currents tend to leave, and thus cause corrosion, Mr. Hering suggests to connect the pipe metallically with a plate or block of zinc. Then there will be a tendency to "suck" the current into the earth, not from the iron pipe, but from the zinc plate, so that the corrosion of the iron pipe is prevented, although the zinc is gradually eaten up.

W. McMurtrie. C. F. Scott. A. Franke. M. von Recklinghausen.
A. von Isakovics.

Mr. Knudson replied to the remarks of Mr. Hering concerning the use of a voltmeter that the latter was only assumed by him to show existing potential differences, and that the conclusions which he drew concerning the current in the pipe were checked by other methods. Messrs. Breneman, Keith, Reed and Richards also participated in the discussion. The question was raised whether it would be advisable to cover gas and water pipes with cement, in order to prevent electrolytic corrosion, but the cost of this remedy was thought to be too high. The

Measuring the current in a pipe.

use of zinc, as suggested by Mr. Hering, to protect pipes is now in large use in boilers and condenser tubes on steamers to prevent corrosion, and has been found very satisfactory. It may also pay to prevent the corrosion of steel docks by connecting them with a plate or block of zinc, which will, of course, be gradually destroyed. Aluminium should, theoretically, be better than zinc, but has not proved so satisfactory in practice, probably on account of the oxide film which is always formed on an aluminium surface.

## FRIDAY MORNING SESSION.

### A Note on the Composition of Electroplating Solutions.

Dr. N. S. Keith presented a paper on this subject, which is abstracted at length on another page of this issue. There was quite a long discussion of this paper. Mr. H. E. Heath discussed the use of unipolar machines as designed by him for electroplating or electrolytical processes. The pulsating current from a commutating machine requires a certain constitution of the solution, while this is not the case with the absolutely constant current obtained from a storage battery or from a unipolar machine. Mr C O Mailloux then spoke at length in a very interesting manner on experiments made by him years ago, together with Dr. Keith. He also discussed a process developed by him by a laboratory study for electrotyping. For this purpose he studied carefully the specific resistance of various solutions, and developed a method in which, by the use of a current density of 500 amperes per square foot, he could reduce the time of the process from six hours to forty-five minutes. He also sketched the mental inertia of the average electrotyper, who prefers to retain a bad process instead of taking the troubles connected with the introduction of a more perfect

WALTER NERNST.

process. Messrs Eddy, Hering, Johnson and Reed also participated in the discussion.

### Modern Electrolytic Copper Refining.

A paper on this subject, by Mr. Titus Ulke was then read, in the absence of the author, by Dr Richards. A full abstract of this paper will be found elsewhere in this issue.

### Determination of Vapor Densities in the Electric Furnace.

A highly interesting paper was then presented by the distinguished guest of the Society, Prof Walter Nernst, of Goettingen, Germany, on a method of determining the density of vapors at temperatures of 2,000 to 2,500 C. The principle of the method is the old one of Victor Meyer, which could, however, not be used up to the present for higher temperatures than about 1,800 C., because no suitable vessels were available. Dr. Nernst had tried to use mixtures of rare oxides, but was so far unsuccessful in this direction, although he thinks that these trials are not hopeless. The firm of Heraeus then succeeded in making vessels of iridium. They are very expensive, and, being brittle when cold, may easily be injured. But they have proven very satisfactory for the present purpose. On account of the high price of iridium, the apparatus must be made in very small dimensions, and this necessary set up new problems which were ingeniously solved by Dr Nernst.

The furnace is a tube of iridium. It is heated from about 2,000 to 2,200° C. by a current of 300 or 400 amp. at 2 to 3 volts. For determining the temperature, the laws of radiation from an "absolutely black body" are used. Below the iridium furnace an electrolytic incandescent filament was provided, which has been tested by photometric methods for different currents. The light radiated from the inside of the tube is reflected by means of a small mirror into a telescope. The current passing through the electrolytic filament is then adjusted until it no longer shows dark against the background of the furnace, nor yet shows bright. The light emission from the furnace is thus determined, and the laws of radiation of a black body are applied.

The vapor density apparatus consists of a thin tube, 15 cm long, 0.5 cm internal diameter, terminating in a bulb 5 cm long, 1 cm diameter, all of iridium, in one piece. The thin end has a brass tube attached at right angles, to which a rubber tube makes attachment to a small glass tube, in which the motion of a mercury meniscus allows readings to be made of the volume of vapor expelled from the tube. Small egg-shaped vessels of iridium are used to contain the substance, and the determination must be made on a very small scale.

Some results obtained with this method were given by Dr. Nernst, the substances so far investigated being water, mercury, sodium chloride and potassium chloride. The surprising accuracy of the method and the great experimental skill of Dr. Nernst were highly commended in the discussion by Messrs. Backeland, Bancroft and Richards.

### Notes on Electric Endosmose.

A paper on this subject was presented by Dr. W. D. Bancroft. He pointed out that whenever we have diaphragms we have the phenomenon of electrical endosmose, and this phenomenon should not be neglected, as is often done in textbooks, which only consider the concentration changes due to the migration of the ions. Dr. Bancroft gave some results of experiments showing that electric endosmose may amount to much more than is generally supposed. The matter is of great importance for technical processes, which require a greater or smaller value of this effect. It is important that to a certain degree it is possible, by proper choice of the diaphragm, to obtain the degree of endosmosis wanted for a special purpose. The question of the possibility of negative endosmose was also discussed.

### Ions and Electrons.

In a paper with this title Dr. L. A. Parsons gave a summary of the researches which have led to the modern electronic hypothesis. A rather full abstract of this paper is given elsewhere in this issue. The paper was not discussed.

### Uniformity of Electrochemical Equivalents.

In a paper on this subject Mr. Carl Hering pointed out that, as long as absolute accuracy is impossible, the establishment of some uniform values for unit and constants is far preferable to continued uncertainty and to the use of different constants for the same thing by different persons or in different countries. In electrochemistry there exists at present a very annoying lack of uniformity in the very constants used in most calculations, namely, in the electrochemical equivalents. While accuracy seems hopeless at present, it is best to enjoy the next best thing, which is uniformity, which is well within reach. Mr Hering proposes to adopt the table of atomic weights of the American Chemical Society. This, together with the legal electrochemical equivalent for silver, namely, 0.001118 gram per coulomb, as adopted by the International Electrical Congress of 1893, gives a complete set of electrochemical equivalents. (The complete and very full table, published by Mr Hering in the January issue of Electrochemical Industry, is based on these values.) The charge of a univalent gram ion (for 0 = 16) becomes 96,538.5 coulombs, which, cut down to four significant figures, which is all, if not more, than the basic figures warrant, becomes 96,540 coulombs. The

electrochemical equivalent of hydrogen on this basis is 0.010441 milligram per coulomb.

In the discussion which followed Messrs. Bancroft and Richards doubted the advisability of adopting a uniform set of values. Dr. Bancroft remarked that careful researches of T. W. Richards have shown that the legal value of the electrochemical equivalent of silver is incorrect, the error being about 0.04 per cent. Mr. Hering replied that, for any practical purpose this difference would be of absolutely no account.

### The Electromotive Force of Alloys.

A brief note on this subject was presented by Dr. W. D. Bancroft on the e. m. f. of an alloy against one of its metals. He pointed out that experimental measurements sometimes lead to an apparent anomaly, which, however, is explained by the fact that in such cases there is no chemical equilibrium. The paper was not discussed.

### The Electrolytic Production of Metallic Compounds.

An elaborate paper on this subject by Prof. C. F. Burgess and Mr. C. Hambuechen was then read by Professor Burgess. A long abstract of the same will be found elsewhere in this issue. There was no discussion of this paper.

## FRIDAY EVENING SESSION.

On Friday evening a joint meeting of the American Institute of Electrical Engineers and of the American Electrochemical Society was held, in the College of the City of New York. President Scott, of the Institute, made the opening remarks. The name of the Electrochemical Society indicates the intimate connection between two branches of science and of industry. The fundamental mysteries of electricity and of chemical affinity are not far apart. He contrasted the rapid development of engineering at the present time with the slow progress in former years. This difference is due to a change of the methods of scientific observation and of scientific generalization on the one hand and in the facility of the inventor and engineer to develop new processes. On the one hand, we marvel at the advance which has been made in science, invention and engineering; on the other hand, we find that in every direction we have only entered upon new fields of nature which lie before us promising and unexplored.

APPARATUS USED IN MR. HAMMER'S EXPERIMENTAL LECTURE.

### Experimental Lecture of Mr. Hammer.

Then followed a very elaborate experimental lecture by Mr. William J. Hammer, on radium and other radio active substances, with a consideration of phosphorescent and fluorescent substances, the properties and applications of selenium and the treatment of disease by ultra-violet light. In this paper Mr. Hammer has collected an enormous amount of information, and, in view of this fact, it seems impossible to attempt to give a brief abstract of it. The paper will be printed in full in the Transactions of both the American Institute of Electrical Engineers and the American Electrochemical Society. The author exemplified certain fundamental principles connected with the phenomena upon which he treated, and in considering these subjects, all of which may be said to be on the border land of science, he brought out, by means of experiments,

lantern slides and illustrations, the practical and commercial side. Some interesting notes were given on the observation made by Heydweiller, who had found that a sample of radium lost in weight one whole milligram in fifty days. On the other hand, J. J. Thomson states that if a square centimeter of surface were covered with pure radium, it would only lose in weight one thousandth of a milligram in a million years. In view of the great discrepancy in these statements, Mr. Hammer corresponded concerning this point with J. J. Thomson, Besquerel, Lord Kelvin, Crookes, Curie and Heydweiller, and the views of these different authors are given in the paper. It appears that Heydweiller's statement, given above, must be looked on as very uncertain. This investigator is continuing his researches. We intend to comment on some special points of Mr. Hammer's paper in our next issue.

## SATURDAY MEETING.

### The Electrodeposition of Metals upon a Rotating Cathode.

A paper on this subject, by Mr. J. G. Zimmerman, was read, in the absence of the author, by Professor Burgess. A rather full abstract of this paper is given on another page of this issue.

The paper was discussed at length by Messrs. Bancroft, Burgess, Eddy, Heath, Hering and Taggart. Mr. Hering expressed his opinion that stirring of the electrolyte would be as good as revolving the cathode, and would be a simpler mechanical arrangement. The principal point is that you always have at the cathode a surface layer of electrolyte containing a sufficient amount of the ions which you want to deposit. Mr. Taggart referred to some recent experiments of Dr. Edgar F. Smith, who, by rotating the anode, considerably reduces the time required for electro-analytical work.

### Electrolytic Conduction Without Electrodes.

Mr. A. B. Marvin reported the results of a series of experiments made to determine quantitatively if it is actually possible to pass a current through an electrolyte without the use of electrodes of any sort, either for introducing the current or for detecting its flow. He first tried to construct a unipolar dynamo, which seemed promising on account of the absence of a commutator, and because the moving conductors can be made short and thick, and hence of low resistance. The dynamo was constructed as shown in the adjoining diagram. The armature consisted of a wooden block B, in which radial channels had been chiseled out, filled with electrolyte. This armature was adapted to sit on the shaft S, and to be revolved by means of the pulley P. Two annular channels M, N were provided to serve as slip rings, from which the current could be led off from the moving part through rubber tubes to a suitable measuring instrument.

To prevent the solution from flying out, because of centrifugal action, the channels and rings were tightly filled with wicking, connection being made with the external circuit by wet cloth brushes bearing on the wicking in the channels. The external circuit consisted of a solenoid of glass tubing filled with the electrolyte, the solenoid serving as the coil of galvanometer. It was found, when the armature was set in motion, that only a very slow speed could be maintained, because of the tendency of the solution to fly out. The experiment was therefore unsuccessful.

In another experiment the principle of the induction motor was applied. It was tried to induce, by means of a rotating field, eddy currents in an electrolyte in a jar which, by reaction, would then tend to revolve with the field. The experiment was not very successful, but at least a tendency to rotate was observed. If it should be possible to obtain rotation in this way, the number of revolutions would depend upon the specific resistance of the electrolyte used, and although a method of determining specific resistances in this way does not appear altogether convenient, the author thinks that in certain special cases it might be of value.

The best results were obtained with a combination of two transformers. The primary of the first was excited from an alternating current power circuit. Its secondary winding, which consisted of a tube of electrolyte, served also as the primary of the second transformer, and the secondary of this second transformer was connected to a telephone receiver. Thus the impulses induced in the core of the first transformer were transmitted through the electrolyte to the core of the second, and thence to the telephone. The trouble with this arrangement was the existence of a magnetic leakage or stray field, which caused the telephone to hum even when there was no electrolyte in the tube representing the secondary of the first transformer and the primary of the second. When the electrolyte was then poured into the tube, the humming in the telephone changed to a loud noise.

The paper was discussed at length by Messrs. Bancroft, Burgess, Carhart, Hering, Hopkins, Reed and Richards. Professor Bancroft referred to some former experiments of Boys, and Professor Hopkins described an apparatus which he had used for the same purpose. There was also some controversy concerning the depositions of metallic conduction and electrolytic conduction.

### Potentials of Zinc in Aqueous Solutions.

A very elaborate paper, by Dr. H. E. Patten and Mr. W. R. Mott, was then read by Mr. Mott. The first part of the paper deals with single potentials of zinc in various aqueous solutions, the principal results being as follows: The measurements of single potentials of zinc in mixtures show that the predominating influence rests with that acid radicle which by itself gives the highest single potential. This is as would be expected from the analogy presented by alloys where the metal of the alloy highest in the electrochemical series controls the single potential. A striking exception was found in mixtures of $KMnO_4$ and $K_2CrO_4$, where the single potential of zinc was much lower than in either alone. One field of great importance where the principle applies with great force is for any solution containing iron salts. In all mixtures in the conduction all salts present participate, although the voltage may be less than the decomposition point of some of the salts. In the case of mixtures, the lowest decomposition point corresponds to that salt giving the lowest decomposition point alone, the highest to that salt giving the highest alone. The single potential of zinc in various solutions of acids, bases and alkali salts varies greatly, the limit being from + 1.00 volt and − 1.00 volt. There is, however, a general centralization of values about + 0.52 volt, and the percentage of the total number of determinations between + 0.42 and + 0.62 volt is little over 50 per cent. Oxidizing reagents, as would be expected, tend to give low values. The so called solution tension of zinc seems to be a "rather elastic quantity." The authors then discuss other influences which must be considered in this connection.

The second part of the paper deals with decomposition points. The authors first discuss the various methods used for this purpose. The first is Le Blanc's method, in which a galvanometer in series with the cell is used to note the point where continuous current begins to flow. This method is rather unsatisfactory, on account of the residual currents, which are never lacking. Other methods are the observation of the voltage when products first appear, discharge potential methods and the method of extending the CR line to the ordinate axis.

The authors then give data on the curves given in their paper, mainly on solutions of sulphates. Large residual currents were noted in $H_2O_2$, and in all solutions containing iron, of which there were several. The polarization voltage for $H_2O_2$ equals zero, and mixtures of ferrous with ferric salts tend to let very large currents pass with very low voltages.

The general principle may be laid down that in electrolyzing the highest current efficiency is realized by avoiding the simultaneous presence in solution of one metal in two or more stages of oxidation.

The CR line of the upper branches of the curves is practically parallel to the CR line of the lower branches, showing that all the salts in a solution share in the conduction equally above and below their decomposition points. The highest decomposition point corresponds to the decomposition point of $ZnSO_4$ in nearly all of the mixtures containing $ZnSO_4$.

### Notes on the Electrodeposition of Nickel.

A paper by Mr. Woolsey McA. Johnson was then presented on this subject. A long abstract of the same will be found elsewhere in this issue.

### A Laboratory Electric Furnace.

The final paper of the meeting was read by Mr. B. McNutt, who described an inexpensive laboratory furnace of the Siemens type. The electrodes are a carbon rod and a graphite crucible. The latter is formed by a cylindrical bundle of arc-light carbon, bored out at the top so as to form a cup in which the graphite crucible is placed. The connection of this crucible with the stranded conductor is made by opening the latter and binding the strands in with the carbons.

There were read by title the following papers: "The Influence of Some Impurities in Salt upon the Yield of Soda by the Amalgam Process," by Dr. J. W. Walker; "The Formation of Nitric Acid under Electric Influences," by Dr. C. W. Volney; "Free Ions in Electrolytic Solutions," by Dr. W. R. Whitney. These papers will be printed in the Transactions of the Society.

### Exhibit of Electrochemical Apparatus.

Mr. A. Eimer, of the firm of Eimer & Amend, then exhibited and explained some improved electrochemical apparatus. Several new types of electric furnaces were shown, among them the forms noticed in Electrochemical Industry, November, 1902, page 112, and April, 1903, page 207. A very interesting new carbon-determining apparatus was also exhibited. It has been designed by Mr. Geo. O. Seward, chemist of the Willson Aluminum Co., and will be described in our next issue.

The presidential address was delivered by Dr. J. W. Richards on Saturday evening. A full abstract of the same will be found elsewhere in this issue.

In the following we give an alphabetical list of all the members and guests who registered at the meeting:

C. E. Acker, Niagara Falls, N. Y.; Mrs. C. E. Acker, Niagara Falls, N. Y.; G. P. Adamson, Easton, Pa.; Geoffrey C. Adams, New York, N. Y.; Robert S. Allyn, New York, N. Y.; C. T. Archer, New York, N. Y.; S. W. Ashe, Brooklyn, N. Y.; Baxter M. Aslakson, Oak City, Pa.; Sherman I. Austen, Mount Vernon, N. Y.; J. W. Aylesworth, East Orange, N. J.; Mrs. J. W. Aylesworth, East Orange, N. J.; Leo Backeland, Yonkers, N. Y.; H. E. Baer, New York, N. Y.; Mrs. D. W. Baker, Jr., Newark, N. J.; E. B. Baltley, Perth Amboy, N. J.; K. B. Bancroft, Ithaca, N. Y.; Wilder D. Bancroft, Ithaca, N. Y.; Chas. Batchelor, New York, N. Y.; Miss Beal, Niagara Falls, N. Y.; F. M. Becket, Niagara Falls, N. Y.; G. F. Bendly, Niagara Falls, N. Y.; S. D. Benoliel, Niagara Falls, N. Y.; A. G. Betts, Troy, N. Y.; S. Lawrence Bigelow, Ann Arbor, Mich.; L. J. Binswanger, New York, N. Y.; C. H. Bissell, Douglaston, N. Y.; Henry S. Blackmore, Mount Vernon, N. Y.; W. S. Block, New York, N. Y.; C. J. Bogue, New York, N. Y.; Malcolm Bonsell, Morristown, N. J.; R. Boudeville, Paris, France; Chas. S. Bradley, New York, N. Y.; C. Brasseur, New York, N. Y.; W. S. Brayton, New York, N. Y.; A. E. Breneman, New York, N. Y., J. Stanford Brown, Reading, Pa.; W. H. Browne, Jr., New York, N. Y.; John Bry, Brooklyn, N. Y.; C. F. Burgess, Madison, Wis.; O. Bussmann, Berlin, Germany; Walter Scott Cameron, New York, N. Y.; Miss E. Cameron, New York, N. Y.; Henry S. Carhart, Ann Arbor, Mich.; Miss M. J. Carum, New York, N. Y.; C. F. Chandler, New York, N. Y.; Carl D. Chasteney, Trenton, N. J.; Virgil Coblentz, New York, N. Y.; H. B. Cobo, New York, N. Y.; Edw. A. Colby, Newark, N. J.; Alfred H. Cowles, Cleveland, Ohio; F. B. Crocker, New York, N. Y.; Mrs. Chas. H. Cromwell, Savannah, Ga.; T. E. Crossman, New York, N. Y.; A. F. Cushman, New York, N. Y.; C. A. Doremus, New York, N. Y.; Mrs. C. A. Doremus, New York, N. Y.; F. E. Drake St. Louis, Mo.; W. Dreyfus, New York, N. Y.; G. Drohegg, Brooklyn, N. Y.; Mrs. G. Drohegg, Brooklyn, N. Y.; Ed. F. Duffy, Yonkers, N. Y.; Joseph A. Dyhnee, Brooklyn, N. Y.; A. H. Eddy, Windsor, Conn.; August Eimer, New York, N. Y.; Wm. M. Eisen, New York, N. Y.; Mrs. Wm. M. Eisen, New York, N. Y.; F. M. Ekert, Mt. Vernon, N. Y.; A. H. Eyles, Philadelphia, Pa.; P. Fireman; C. W. Fletcher, New York, N. Y.; R. A. Fliess, East Orange, N. J.; Hans Foerstering, Perth Amboy, N. J.; F. Forbes, New York, N. Y.; E. A. Fourneau, New York, N. Y.; C. E. Freeman, Chicago, Ill.; A. B. Frenzel, Denver, Colo.; S. E. Getty, Yonkers, N. Y.; F. A. Godley, New York, N. Y.; G. McM. Godley, New York, N. Y.; W. E. Goldsborough, Lafayette, Ind.; F. Gottsch, New York, N. Y.; Albert C. Hale, Brooklyn, N. Y.; Mrs. A. C. Hale, Brooklyn, N. Y.; F. E. Hale, New York, N. Y.; W. B. Hale, Chicago, Ill.; Chas. M. Hall, Niagara Falls, N. Y.; A. P. Hallock, New York, N. Y.; D. Hand, Newark, N. J.; Edwin Harrington, Yonkers, N. Y.; Edw. Hart, Easton, Pa.; J. C. Hatzel, New York, N. Y.; H. O. Havemeyer, Jr., New York, N. Y.; H. E. Heath, Windsor, Conn.; M. Heike, New York, N. Y.; Carl Hering, Philadelphia, Pa.; Edwin F. Hicks, New York, N. Y.; B. H. Hite, Morgantown, W. Va.; N. M. Hopkins, Washington, D. C.; R. L. Hopkins, Passaic, N. J.; George M. Howard, Philadelphia, Pa.; Henry Howard, Brookline, Mass.; E. J. Hutchinson, Cincinnati, Ohio; Mrs. E. J. Hutchinson, Cincinnati, Ohio; M. R. Hutchinson, New York, N. Y.; R. W. Hutchinson, Jr., Brooklyn, N. Y.; Alois von Isakovics, New York, N. Y.; Mrs. A. von Isakovics, New York, N. Y.; H. A. Jackson, New York, N. Y.; W. McA. Johnson, Hartford, Conn.; Franklin H. Kalbfleisch, Babylon, L. I.; Alfonse Kaufman, New York, N. Y.; N. S. Keith, New York, N. Y.; Mrs. Keith, New York, N. Y.; J. J. Kennedy, New York, N. Y.; Wm. Houston Kenyon, New York, N. Y.; Edw'd F. Kern, Troy, N. Y.; C. V. Kerr, New York, N. Y.; E. C. Klipstein, New York, N. Y.; A. A. Knudson, New York, N. Y.; Wm. Kuchrow, Brooklyn, N. Y.; W. S. Landis, Bethlehem, Pa.; Palmer H. Langdon, New York, N. Y.; Jos. Law, New York, N. Y.; E. J. Lederle, New York, N. Y.; C. E. Lockwood, New York, N. Y.; M. Loeb, New York, N. Y.; E. G. Love, New York, N. Y.; L. R. Loveman, Orange, N. J.; Arthur M. Lumley, New York, N. Y.; L. Lyndon, New York, N. Y.; F. Machalske, New York, N. Y.; Barry MacNutt, Bethlehem, Pa.; I. J. Macomber, Bethlehem, Pa.; C. O. Mailloux, New York, N. Y.; M. E. Malthy, New York, N. Y.; Cloyd Marshall, New York, N. Y.; K. G. Martin, New York, N. Y.; T. C. Martin, New York, N. Y.; A. B. Marvin, Washington, D. C.; H. T. Matthew, New York, N. Y.; F. J. Maywald, Brooklyn, N. Y.; W. A. McCoy, Perth Amboy, N. J.; Douglas C. McMurtrie, New York, N. Y.; Wm. McMurtrie, New York, N. Y.; Ralph McNeill, New York, N. Y.; H. A. Metz, New York, N. Y.; Dwight D. Miller, New York, N. Y.; J. H. Miller, New York, N. Y.; P. S. Miller, New York, N. Y., Jos. S. Mills, New York, N. Y.; I. F. Moltkehansen, Perth Amboy, N. J.; A. 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Ries, New York, N. Y.; Mrs. E. E. Ries, New York, N. Y.; I. L. Roberts, New York, N. Y.; E. F. Roeber, Philadelphia, Pa.; Mrs. E. F. Roeber, Philadelphia, Pa.; A. J. Rossi, New York, N. Y.; Mrs. A. J. Rossi, New York, N. Y.; Samuel S. Sadtler, Philadelphia, Pa.; P. G. Salom, Philadelphia, Pa.; E. S. Sargent, New York, N. Y.; G. Saunders, Rutherford, N. J.; Carl Schlegel, New York, N. Y.; B. E. Schlesinger, Boston, Mass.; Emil Schmidt, New York, N. Y.; Mrs. Emil Schmidt, New York, N. Y.; F. E. Schmitt, New York, N. Y.; George P. Scholl, Philadelphia, Pa.; Carl R. Schultz, New York, N. Y.; C. Walter Schultz, New York, N. Y.; R. C. Schuepphaus, New York, N. Y.; Walter Schwabe, Rutherford, N. J.; J. A. Secor, Brooklyn, N. Y.; S. Sheldon, Brooklyn, N. Y.; Louis Simpson, Ottawa, Canada; Edmund S. Smith, Niagara Falls, N. Y.; Edw. W. Smith, Philadelphia, Pa.; H. F. Smith, Concord, Mass.; W. L. Smith, Concord, Mass.; Chas. F. Scott, Pittsburg, Pa.; C. C. Speiden, Summit, N. J.; E. A. 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Weidemann, New York, N. Y.; G. A. Wells, New York, N. Y.; Benj. R. Western, New York, N. Y.; Gus. Westman, New York, N. Y.;

Edward Weston, Waverly Park, N. J.; Joseph Wetzler, New York, N. Y.; C. E. Whitney, New York, N. Y.; C. E. Whitney, Mt. Vernon, N. Y.; Jos. Whitney, Homesdale, Pa.; F. J. Wiechmann, New York, N. Y.; Wm. S. Wiedon, Schenectady, N. Y.; Henry Wigglesworth, New York, N. Y.; Harvey Wiley, Washington, D. C.; B. T. Witside, Yonkers, N. Y.; Alfred Wohlauer, Berlin, Germany; W. A. Wood, New York, N. Y.; Frank M. Zeller, Philadelphia, Pa.

## NOTES ON THE ELECTRODEPOSITION OF NICKEL.

In the following we give an abstract of an interesting paper read by MR. WOOLSEY MCA. JOHNSON at the New York meeting of the American Electrochemical Society. His paper is supplementary and explanatory of his article published in the February issue of ELECTROCHEMICAL INDUSTRY (page 212):

The use of hot solution (above 40° C.) has been much praised in the technical press, and, in fact, has been given, in the author's opinion, undue prominence. In the first place, the statement that it is impossible to deposit thick coherent coatings at a low temperature is untrue. Perhaps the best piece of electrolytic nickel which the author has ever seen was a chance deposit on the wire suspending a plater's basket. The solution was cold, but the fortuitous use of a low-current density and the great care taken to keep a clear solution caused this remarkable deposit, which was as hard as steel, perfectly reguline and possessed a dull silver finish. In the second place, a hot solution would be used in any electrolytic nickel refining process, not for the reason that thick platings can only be made from a hot solution, but because the voltage can best be reduced by heating the solution as high as possible without causing undue evaporation and consequent creeping of nickel salts. The cost of power in an electrolytic-nickel process would be a very large percentage of the total cost, as from five to ten times as much power would be used in refining nickel as in refining copper. This is because of the self-evident fact that nickel must be deposited from an alkaline or neutral or very slightly acid electrolyte, because of its high electropositive character; while copper can be deposited from a strongly acid solution, because it is 0.567 volt lower in the electrolytic series. Again, if any working-current density were used, say 15 to 30 ampères per square foot, to cut down the interest charge on metal tied up in the vats, the electrolyte would warm up by the $C^2R$ loss in the vats. In fact, if a cold electrolyte were desirable, which it is not, for the commercial reasons above stated, it would be necessary to place refrigerating pipes in the storage vats to keep the temperature of the electrolyte below 40° C.

There is an advantage in the use of hot solution, namely, to be allowed the use of a high current density and to facilitate circulation. The advantage of hot solutions in making tough deposits has been known to practical electroplaters in this country for some fifteen years. There are several secret "dopes" which can be used to make a smooth homogeneous deposit. The author has experimented with 15 or 20 of these, and it is really surprising to note the benefit that arises from the addition of a very, very small amount, say, one part in a thousand. The excellence of the Balbach nickel cathodes was partly due to the use of a hot solution, which, of course, was unavoidable, but more to the use of an efficient secret "dope" which was discovered by Mr. William Thum.

The use of a hot electrolyte, which is unavoidable for the commercial and practical reasons above stated, is bad, in that it accelerates the reaction velocity of the basic iron, cobalt and nickel salts in the electrolyte. This means that the electrolyte becomes turbid, and a turbid electrolyte always means warty, poor deposits.

The author then discusses the reasons why the use of a hot electrolyte prevents the curling up of nickel deposited at high current density. This is, to his mind, directly connected with the formation of nickel-hydrogen alloys.

It has long been known that many metals are capable of occluding hydrogen, and that this absorption profoundly modifies their magnetic, physical and electrochemical properties. In electrolytically depositing nickel, nickel hydride is always formed, as is shown by the decreased current efficiency, even when no hydrogen is visibly evolved. It is also proven by the fact that nickel electrolysis is not a reversible process, like copper refining.

Electrolytic nickel, or, to be exact, nickel hydride, is deposited under a considerable electrochemical stress. The molecules of the nickel hydride are in a state of abnormal strain—something similar to the strain of the molecules in tempered steel. This can be proved physically by the following evidence: Nickel was electrodeposited on a malleable nickel cathode sheet, 18 x 12 inches, which fitted in a groove in the end vat, which was 12¼ inches wide. The groove was made of slats, ½ x ½ inch in cross section, nailed to the vat. The surface exposed was about 18 x 11⅞ inches. At the end of six days' deposit out of a hot solution, the electrolytic sheet, still adhering to the soft sheet, was wedged in so strongly that two men were required to pull it out. The whole sheet was now elastic. In addition to the potential energy of electrolytic solution, as measured by the potentiometer, there was also the potential energy of an elastic body under strain.

Now this elasticity and "overvoltage" (which is really electrolytic elasticity) both gradually decrease with time or with increase of temperature. Electrolytic nickel, which is as hard as steel and brittle, becomes as soft as lead on annealing. This overvoltage decreases with time and heat also. Both these properties seem to be dependent on the amount of hydrogen co-deposited.

Take a piece of stiff paper and wet one side of it; allow it to stand, and it will be observed that it curls up. Allow it to stand still longer, and it will slowly unroll. What has happened? The surface wetted becomes soft as annealed electrolytic nickel becomes soft. The other side is elastic, as electrolytic nickel is elastic. Unequal strains are set up, and the sheet curls up. When the annealing action of the water soaking through the sheet makes the whole sheet limp, these strains are equalized and the sheet uncurls.

Precisely the same thing happens in the electrodeposition of nickel. This "curling up" of electrolytic nickel is caused by the fact that there is an unequal strain between the inside and outside layer. The inside layer, when deposited, had the same abnormal strain, but with time this tension has become more normal by a slow annealing action of the nickel hydride. The outside layer has had, however, no time for the molecules to adjust themselves, and consequently the tension is greater on the outside than on the inside. The curling is always such that the outside layer (or last deposited) is on the concave side of the bending.

It has been observed that nickel will curl when the temperature of the electrolyte is 60° C. if the current density is too high, or if the deposit is made on a heavily oiled or graphitized surface. This layer could not have been uniform, and consequently there were parts of a surface where nickel was thin, causing lines of weakness where the nickel cracked and curled off. The higher the current density, or, better still, the "electrovoltage," to use the scientific term, the greater the strain. Nickel will often stick to a clean surface when it will curl up in a few hours from the same surface when oiled. Nickel will stick to a matte or rough surface when it will curl up from the same surface smooth. If the proper "dope" be added to the solution, nickel has a remarkable hardness and toughness. Mr. Thum took one of his cathodes, ⅛ inch thick, placed it against a strong wood frame, and fired at this point blank with a Winchester rifle. The bullet was stopped by the nickel cathode and drew out a long cone at the end of which was found what was left of the bullet—nothing. This is shown in the adjoining sketch of Mr. Thum. The left hand diagram how the section of this long cone. The diagram in the center is the section of a test piece penetrated by a higher velocity projectile being drawn out somewhat longer before giving away under the strain. Samples of soft boiler steel, tested at the same time, were both penetrated, but showed

ragged edges, somewhat like the right-hand diagram. The experiment simply showed that, at least to tensile strength and ductibility, the nickel was superior to the steel plate.

If the electrolyte be made gas-free by allowing to drip through a vacuum and be kept in a substantially gas-free condition, it will be found that the tendency to curl up of nickel deposited from this electrolyte is diminished. A large part of the hydrogen which is ordinarily occluded by the nickel is dissolved by the electrolyte, because the electrolyte has its hydrogen pressure reduced to a low limit. As a consequence hydrogen is always passing from a state of the nickel hydride to the state of hydrogen dissolved in the electrolyte. By this means it is possible to make heavy platings of nickel, provided the circulation of the gas-free electrolyte keeps pace with the

EXPERIMENTS OF MR. THUM ON THE MECHANICAL RESISTANCE OF NICKEL CATHODES AND OF STEEL.

formation of hydrogen at the nickel cathode. This process and apparatus for it have been patented by the author. The tenacity and reguline character of nickel deposited from a gas-free electrolyte is greatly benefited by this, and for certain purposes, such as the manufacture of "starting sheets," this device would be of value. For general refining purposes it has, in the author's opinion, small worth.

Mr. Johnson showed several pieces of electrolytic nickel, 4 x 6 inches, deposited under different conditions. Two of these were badly "curled up" by the use of excessive current density in a hot solution. A third specimen, deposited at a lower "electrode voltage," was smooth, but somewhat brittle. A fourth one was of remarkable physical properties, tough, malleable and smooth. This had been deposited from an electrolyte kept gas-free by use of the vacuum.

## CONDITIONS OF PROGRESS IN ELECTROCHEMISTRY.

Dr. J. W. Richards' splendid presidential address, delivered at the recent New York meeting of the American Electrochemical Society, is a lucid and highly interesting analysis of the conditions which make progress in electrochemistry possible. It is one of the finest presidential addresses delivered before technical societies in recent years, and it is with great regret that, owing to the limitation of space, we can give in the following only an abstract of this address, while for the full address the reader must be referred to the Transactions of the Society.

"To live is to progress, and to progress is to live. A science which does not progress, petrifies. As the progress of electrochemistry is, however, only one phase of scientific progress in its more general sense, a clear understanding of the laws governing the latter will teach us as their corollaries the conditions for progress in the former. Science advances in many different ways, along many different paths and by many different agencies." For the purpose of his discussion the author classifies this subject under six headings, as follows:

I. DISCOVERY OF NEW FACTS IN ELECTROCHEMICAL SCIENCE.

"I place this as the corner-stone of progress in our science. Given a freshly-flowing current of new electrochemical facts, and all the other elements of progress have a chance to exist. No less certain than this is the location of the birthplace and the identity of the sponsers of these newly-born facts. The birthplaces are chemical, electrical and physical laboratories; the sponsors are the investigators, the searchers after truth—the professors, students, employees, private investigators and all who, with the insatiable thirst for more knowledge, are pushing back the thick curtain of the unknown, which hems us in so closely on every side. The elect among these workers, the highly-favored few, are the professors of electrochemistry provided with well-equipped electrochemical laboratories. They are in the position to do or to direct the most valuable investigations, and are also under the moral obligation to publish freely to the world all that they discover. The giants of the electrochemical fraternity are in this class: Davy, Faraday, Bunsen, Arrhenius, van't Hoff, Ostwald, Nernst, Moissan. The labors of such workers, given to the world in their publications, form the *body* of electrochemical science, and their thoughts—its *soul*. Such are the heroes of science; men who work for the work's sake, who sacrifice time, money and often health to increase the boundaries of our knowledge, and then keep nothing back. These are the sort of men whose grateful memory we should perpetuate in bronze and marble, as well as in our literature. Great wealth has been amassed by the application of the facts discovered by these pioneers, and yet the facts are at the command of anyone who will read our literature. And there are others of the rank and file following cheerfully the same paths; our journals and transactions teem with the results of new researches, by which the humble worker in one corner of the scientific field gains the knowledge gleaned by many workers, and in return he contributes what he can, and every such contributor, mark it well, receives in return a hundredfold for all that he himself contributes."

The author refers to the fact that the German-speaking countries count up alone at their universities and technical schools 15 chairs of electrochemistry and 12 electrochemical laboratories, which have been the source of the greater part of the advance of electrochemical science in the last ten years. He asks: "Are we not out of comparison with Germany in that respect?" and urges that America should soon begin to establish chairs of electrochemistry and build well-equipped laboratories to go with them. Then our boast, that America is "the electrochemical center of the world," might begin to be more than the empty boast of a successful money maker; then we may begin to be an *illuminating* center, radiating knowledge to the rest of the world.

In place of professors and professional laboratories, however, America is blessed with another class of investigators, who are no less industrious in acquiring facts, and to whom a large part of our commercial success is directly ascribable; that is the small army of patient investigators in the laboratories of our industrial plants, who are searching over ground not yet explored and accumulating facts of value in their special industrial lines. They are, however, generally not at liberty to publish what they discover, but Dr. Richards urges that, *when the research has achieved its financial purpose, the scientific results should be given to the world.* In other words, when the laboratory experiments have led up to the technical process, and the latter has been protected by patents, then the scientific principles discovered during the investigation should be freely published.

II CLEARER KNOWLEDGE OF THE LAWS CORRELATING THESE FACTS.

"By means of facts, correlating, discussing and deducing therefrom, we arrive at a knowledge of the laws of the science, the rules governing its various phenomena and according to which its manifestations invariably proceed. Such deductions are the goal of pure science; they contain no element of speculation, hypothesis or theory, and represent man's deepest insight into the phenomena of nature." The author refers to the work of Faraday, Ohm and Joule, and warns us not to think that there remains very little more in the nature of generalizations to be discovered. We could not make a greater mistake. If facts are discovered, the recognition of unforeseen generalizations and the establishing of new laws is bound to follow.

Such discoveries are usually the privileges of the experimenter, as he gets the facts at first hand. "The electrochemist not blessed with laboratory facilities has, however, free entrance to this field. He may be only a student, a looker-on

at what others are doing, a reader of the newly discovered and recorded facts, but if he is at the same time a thinker, a compiler, an analyst, with the power of collating, dissecting and deducing, he may, in the seclusion of his study, discover laws which escape the observation of others less studious, and thus render a service of the highest value to the science."

III. MORE RATIONAL THEORIES OF THE WHY AND WHEREFORE.

"As soon as facts accumulate and laws are discerned, the scientist inevitably begins to reflect on the why and wherefore. He commences to search for relations, to imagine connections and dependencies and to make pictures of the mechanism of the phenomena." The author refers to Dalton, Arrhenius and Nernst, and continues: "Thus there are theories and theories, some poor, some good and some almost perfect in their applicability, since, *granting their premises*, they give an explanation satisfactory to the mind of all observed phenomena. Such theories are not only allowable, but necessary. We must have them much as an artisan must have a working drawing of the machine he will construct. The drawing is but paper and ink, which never moves or works, but it guides the workman in putting his ideas into realities. So theories help us to handle mental conceptions as if they were concrete things, and thus to imagine and discover relations and generalizations which would otherwise be beyond our mental grasp."

"The danger of the development of a science comes when a theory, by being believed too implicitly, and by not being open to constant revision, becomes a straight-jacket for the growing science. Like a 'creed outworn,' it stifles criticism, warps the judgment, engenders blindness and bias in its adherents and undue hostility and acrimony in its opposers. We should be slow in revising our theories, or in discrediting a theory which has done us good service in its day, just as we are conservative in correcting our 'confessions of faith' or indulgent and sympathetic with the weaknesses of a faithful old servant. But, after all, when a theory has come to be considered so firmly fixed as to be above criticism, or so certainly true as to be above the possibility of revision, or so well established as to thunder its excommunications on those who dare to think or believe otherwise, such a theory had better be placed at once in the museum of scientific petrifications, where it properly belongs and where it can do no further harm."

"If science is progressing, theories must progress, too. They will be outgrown; much light will give way to more light; imperfect pictures of phenomena, founded on crude assumptions, must be replaced by better pictures, corresponding more accurately to the newer and the larger truth, and then progress begins anew. All theories have been of some use in their day. They have helped men to grasp concretely evanescent, immaterial phenomena; they have very often been splendid guides to further experiment and new discoveries; they have at times been so helpful that many have mistakenly thought them infallible, and, lastly, they have been stepping stones to better theories. One great hindrance of scientific progress is the common human weakness of becoming partisans of a theory."

"The biased investigator, with a theory to support, is apt to support it at all hazards. He catches at every straw which helps to establish his preconceived idea of what he should find, and is virtually blind to facts which disprove his ideas; while his report of his work, flickering through his perverted imagination, gives as often as not an entirely distorted picture of the facts."

"The pitfall is particularly dangerous to the young and ardent investigator. Believing almost implicitly in the rectitude and ability of his instructor, he takes to his professor's hobby with enthusiasm, and spurs it on to feats which make more careful scientists shudder."

"To make a specific application of these remarks, who has not felt that the most effective blows dealt the present theory of electrolytic dissociation have come from the excessive zeal of its warmest adherents? Out of their camp has proceeded half-fledged treatises on the theory, such as inaugural dissertations of would-be doctors of philosophy or text-books compiled by *privat-docents*, in which the theory was simply done to death and made a laughing stock. Have we not met writers or lecturers on this theory who shunned a fair debate on their written or spoken statements, because, forsooth, they were themselves conscious that they had surpassed the safe bounds of reasonableness in those statements? Such an attitude and such results are the consequence of holding a theory too tenaciously, and not 'subject to revision.' There are scientific zealots as well as religious bigots, and the one does as much harm to the progress of true science as the other does to the development of pure religion."

(*To be continued.*)

## THERMO-ELECTROMOTIVE FORCE WITHOUT DIFFERENCE OF TEMPERATURE.

We have repeatedly referred in these columns to the important and very interesting recent thermo-dynamical investigations of PROF. HENRY S. CARHART, Ann Arbor, Mich., on concentration cells, and on galvanic cells in general. His results were given in two papers read before the American Electrochemical Society, at the Philadelphia and Niagara Falls meetings (ELECTROCHEMICAL INDUSTRY, Vol. I, pp. 2, 58), and in two papers published by Dr. Carhart in the September and January issues of ELECTROCHEMICAL INDUSTRY (pages 9 and 178). In his investigations relating to the *rôle* of thermo-electromotive forces in a voltaic cell, he has applied them to the analysis of the temperature coefficient; to the localization of the absorption and generation of heat at the electrodes; to the variation of the electromotive force with the concentration of the electrolytes, and to the electromotive force of a concentration cell. Dr. Carhart's view of the temperature coefficient as the difference of the electrolytic thermo-electromotive forces per degree at the two electrodes, is sustained by the measurements in a most satisfactory manner. Dr. Carhart has also shown mathematically the difference in heating at the electrodes when a current flows to be an extension of the Gibbs-Helmholtz principle, and has confirmed the results by quantitative experiments.

In the discussion following his Niagara Falls paper before the American Electrochemical Society, and in a recent German technical journal, the objection had been made to these applications, particularly as regards the concentration cell, that such thermo electromotive forces come into play only when the junctions are at different temperatures. It is to this objection that Dr. Carhart replies in a paper read at the New York meeting of the American Electrochemical Society, an abstract of which follows:

The inquiry is naturally divided into two parts: First, the existence of thermo-electromotive forces without difference of temperature at the junctions, and, second, the resultant thermo-electromotive forces in a closed circuit.

The Peltier phenomenon is itself sufficient evidence that it is not necessary to heat a junction in order to excite there an electromotive force. In fact, this phenomenon is but a single example of a very general law, namely, that when a current flows across any part of a conducting circuit, which is the seat of an electromotive force, energy is either given to the current or is taken from it, according as the electromotive force at the point is directed with the current or against it. Thus, in a direct-current motor the current does work against the counter-electromotive force generated by the motor, and the product of the motor is mechanical motion. In a "booster," on the other hand, the generated electromotive force has the same direction as the current, and the current receives energy from the generator. Similar relations exist in a storage battery. Now, unless the devices employed are such that the work done by the current at the seat of an opposing electromotive force takes some other form of energy, the circuit is invariably heated. In the opposite case the conductor gives us heat energy and cools. In a Daniell cell, for example, the thermo-electro-

motive force at either electrode is directed from the electrolyte to the metal. At the iron, therefore, heat is generated, while at the copper it is absorbed, and the flow of current produces a difference of temperature between the electrolytes surrounding the electrodes. These temperature changes have nothing to do with the resistance of the cell, and they are proportional to the first power of the current.

The direction of the thermo electromotive force at a copper-iron junction at moderate temperatures is from copper to iron. In accordance, then, with the general law, when a current is sent across this junction from iron to copper heat is generated and the junction is heated. If the current passes from copper to iron, heat is absorbed and the junction is cooled. The Peltier effect proves the presence of an electromotive force at the contact of dissimilar substances, and the value of this electromotive force is determined by the usual thermo-electric experiments. This statement is justified by the measurements made on the Daniell cell before alluded to. The following are the results: The temperature difference between electrodes observed in a Daniell cell was 0.0165, while the temperature difference calculated from thermo-electromotive forces was 0.0160.

Helmholtz remarks, in his celebrated memoir on the "Thermo-dynamik Chemischer Vorgäenge," as follows: "There are, besides, differences of heating at the two electrodes, which, in their manner of appearance, are similar to Peltier's phenomena in the case of thermo-electric currents, even though they are perhaps of different origin." Helmholtz said "perhaps" because experimental evidence was lacking at that time, but the agreement now established by Dr. Carhart between theory and observation justifies the statement that they are the same in origin.

Reference is made to a very striking illustration of the general law under discussion. It has been brought out by Duddell, in London, within the past year. He finds an electromotive force between carbon and carbon vapor, and it is directed from the latter to the former. When, therefore, the arc is formed heat is generated at the positive carbon, where the current flows against this thermal electromotive force, and is absorbed at the negative carbon, where it flows in the same direction as the electromotive force there. This is an interesting explanation of the higher temperature of the positive carbon.

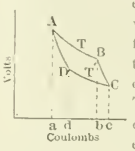
It is not open to question, then, that there exists an electromotive force at the junction of two dissimilar substances. The other question remains to be answered. We have been taught that the thermo-electromotive force integrated around a circuit, composed of two or more metals, vanishes when the whole circuit is at one temperature. This law is undoubtedly true for circuits wholly metallic. The denial of it would involve the absurdity of self-acting thermo-electric engine, continually converting the heat energy of the surorundings into the energy of an electric current, *without any change in the circuit which could limit the process.* It would be a kind of perpetual motion, by which the kinetic energy of diffused heat might be converted into potential energy, or be made more available. The integrated electromotive force around such a circuit, therefore, vanishes, unless there are differences of temperature.

When the surface is partly metallic and partly electrolytic, the case is quite different. Imagine a zinc rod bent in the form of a U, and let the two ends be immersed in a solution of zinc sulphate. If, now, one side of such a cell be slightly warmed, the warmer end of the rod becomes the positive electrode of a thermo-electric cell. But the flow of current produces changes in the concentrations at the electrodes, with a resulting back electromotive force. If the equalization of concentrations by diffusion is prevented, the electromotive force becomes zero by the decrease of the thermo-electromotive force at the electrode and its increase at the negative.

If two zinc rods joined by a zinc wire are immersed in solutions of zinc sulphate of different concentrations, the combination is a concentration cell. The current through the cell is from the more dilute to the less dilute solution, and the flow of current acts to equalize the concentrations and reduce the electromotive forces. Hence the device as a thermal engine is self-limiting. It can convert some of the equally-diffused heat of its surroundings into electric energy, but it cannot do so continually, and can repeat the process only by having the cycle of operations reversed.

Dr. Carhart then gives a very lucid explanation of the problem by applying to it a complete Carnot's cycle. The cell may be contained in a case impervious to heat except through the bottom, and the porous partition separating the two solutions may be a good conductor of heat, but preventing sensible admixture of the liquids. All parts of the cell may then remain at the same temperature. The usual cycle of the well-known four operations of Carnot's cycle may now be carried out.

The first operation is to place the cell on a heat-conducting stand of the temperature T, and let a small current flow till its electromotive force has fallen from the value denoted by the ordinate *Aa* in the figure to that denoted by *Bb*. The temperature remains at the value *T* by absorption of heat from the heat-conducting stand. The change in concentrations causes the decrease of electromotive force, and the cell works along the isotherm *AB*. Heat is absorbed because the thermo-electromotive force working with the current at the positive electrode is greater than the opposing thermo-electromotive force worked against at the negative. During this operation the work done by the cell is equal to the area *ABba*. The co-ordinates are electromotive force (volts) and quantity of electricity (coulombs).




The second step consists in transferring the cell to a stand which does not conduct heat and passing the current till the electromotive force falls to the value *Cc* and the temperature to *T'*. The cell then works along the adiabatic *BC*. Its temperature falls because the heat absorbed at the positive electrode is greater than the heat generated at the negative electrode. The internal resistance of the cell and the current are both supposed to be so small that the heat generated within the cell, proportional to the square of the current, is infinitely small compared with quantities proportional to the first power of the current. In this second operation the electromotive force falls for two reasons—the change in the concentrations and the fall of temperature. The curve *BC* is therefore steeper than the curve *AB*. The work done by the cell during this second stage is represented by *BCcb*.

For the third step of the process the cell is transferred to a heat-conducting stand at the temperature *T'*, and a reverse or charging current is passed through it at the lower temperature and electromotive force till the work done on the cell (not on its external circuit) along the lower isotherm *CD* equals the area *CDdc*. This work must be considered as negative. The cell gives out heat to the stand, the reverse current augments the difference of concentration and the electromotive force rises.

In the fourth step the cell is transferred to the first heat-conducting stand again, and a charging current is passed till the temperature of the cell rises to T. The opposing thermo-electromotive force is now greater than the direct, and heat is generated into the cell. Work done on the cell along this adiabatic *DA* is equal to the area *DAad*.

The cell is completely reversible, and has been brought back to initial conditions in all respects. It has at the end of the process the same internal energy, whether chemical or thermal, as at the start, while the excess of work done by the cell during the entire cycle over the work done on the cell is donated by the area *ABCD*. This energy is derived from the heat taken in during the first operation, with the usual ratio for the efficiency of a reversible process. The cell works like any other

thermo-dynamic engine, which is carried through a complete cycle of operations, taking in $H$ units of heat at the higher temperature $T$, and giving out $H'$ units at the lower temperature $T'$.

A concentration cell carried through such a cycle may convert heat into electrical energy indefinitely. So may a steam engine and an electric generator. If the cell does not work in a cycle, its function is then limited to the first operation along the isotherm $AB$. Gas, under pressure in a tank, may do the same thing. An essential element is the presence of stress. In the concentration cell this stress is the difference of the thermo-electromotive forces at the two electrodes. There is no question that there is such a difference, and it is not neutralized by a thermo-electromotive force between the two solutions.

A temperature coefficient is the difference of the thermo-electromotive forces per degree between the metal and the electrolyte at the two electrodes. Whenever a cell has a positive temperature coefficient, it absorbs heat and converts it into electric energy. A concentration cell has an electromotive force proportional to its absolute temperature. It also converts heat from its surroundings into electric energy. It does it by means of the fact that the thermo electromotive force at the positive electrode is greater than that at the negative. Its electromotive force is therefore thermo-electric. If any part of its electromotive force is derived from internal energy, such as the heat of solution, the argument is in no way invalidated. To the extent that it takes in heat from its surroundings and converts it into electric energy, its electromotive force is purely thermo electric.

It is obvious that any reversible voltaic cell, having a positive temperature coefficient, may be carried through such a cycle, and the area $ABCD$ will represent the work done by the internal energy of the cell. The electric pressure, by means of which this heat energy is transformed, is denoted by the second term of the Helmholtz equation, expressing the thermo-electromotive force of a voltaic cell. This term is the integrated value of the thermo-electromotive forces in the circuit. Any voltaic cell with a positive temperature coefficient converts absorbed heat into electric energy. A concentration cell is an extreme type, which absorbs all, or nearly all, of its electrical output as heat.

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles in Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

By Carl Hering.

## INDUSTRIAL ELECTROCHEMISTRY.

*Treating Nickeliferous Copper Mattes.*—In the Transactions of the Am. Electrochem. Soc., Vol. I, page 95, Ulke describes a process for treating such mattes. Guenther has now devised a somewhat similar one in Borchers' laboratory, although different in important points, as appears from the description given by von Kügelgen in the *Zeit. f. Elektrochemie* of March 19th. Guenther, like Ulke, uses the copper-nickel alloy as the anode in an acid electrolyte for the production of copper at the cathode. The solution thus obtained during the process is treated chemically to separate the last traces of copper and iron from the nickel. The nickel is finally extracted electrolytically. But while Ulke uses for this an ammoniacal nickel solution with insoluble (lead) anodes, Guenther uses an acid solution and soluble anodes. Guenther's alloy contained 20.43 per cent. Cu, 50.18 per cent Ni, 21.23 per cent. Fe and some sulphur and carbon. This was cast into anodes. Between two anodes a copper sheet was placed as cathode. The electrolyte consisted of an acid copper sulphate solution of 17.5 Baumé, and contained 38.4 gr Cu and 62.7 gr free acid per liter. The current density was 200 ampères per square meter. The voltage in the beginning was 0.56, but soon increased to 1.16, at which value it remained. The ampere hour efficiency was between 95 and 97 per cent. When the solution became poor in copper, and contained only about 0.5 per cent., the copper deposit began to become spongy; but, with lower current densities, good copper could even then be obtained. Concerning this step of the process, he sums up his results by saying that a copper-nickel-iron alloy of the composition mentioned can be used as anode in regular, continuous operation, and electrolytic copper of the best quality is thereby obtained. It is, however, necessary not to allow the copper contents in the bath to decrease considerably below 1 per cent. if it is desired to use the high current density (200 ampères per square meter), which is preferable for several reasons. The last traces of the copper must be removed from the solution by chemical means. The copper contents of the alloy is not sufficient to furnish all the copper deposited at the cathode, hence the difference must be added to the bath at continuous intervals, in form of a solution which is rich in copper, but may contain iron and nickel. Such a solution is easily obtainable in this process. In order to avoid an increase of sulphuric acid, this added solution should contain a correspondingly smaller amount of acid. The second step of the process is the separation of the last traces of copper from the solution, and the separation of iron and nickel by chemical means. Guenther thinks that these traces can be most easily removed by means of precipitation by hydrogen sulphide. For the separation of the iron from nickel, he recommends separating the nickel in the form of nickel ammonium sulphate, which crystallizes out when the solution is cooled, while the iron remains in solution. If the iron and nickel are present in a proportion of one to fifteen, this separation is nearly quantitative. If this proportion is one to two, about 90 per cent. of the nickel is separated. The third step of the process is the electrolytic treatment of the nickel salt for the production of metallic nickel. Guenther first tried insoluble (lead) anodes and various electrolytes, but he found two disadvantages, one being the low solubility of nickel ammonium sulphate and the other the relatively high voltage required. He thinks the latter is due to the fact that at the anode lead peroxide is formed, together with lead sulphate. The former, which is a good conductor and firmly adherent at the anode, will include the particles of lead sulphate, which is a poor conductor, and in this way a layer of high specific resistance is formed. This formation is prevented by using soluble anodes. Moreover, it is desirable to use for the electrolyte a nickel salt which is more soluble than nickel ammonium sulphate, and has a smaller tendency to crystallizing out with a decreasing temperature. The nickel ammonium sulphate obtained in the former steps of the process is therefore transformed into $NiSO_4$. For commercial reasons, it is necessary to recover the ammonia. The principle of his process is to utilize the anodic energy of the current by making the electrolyte at the anode a mixture of two salts, one of which will electrochemically attack the metallic anode, while the other decomposes the soluble metallic compound thus formed nearly at the moment at which it is formed, the result being the regeneration of the solvent and the formation of an insoluble salt, such as is useful for pigments. This idea led to the necessity of a diaphragm separating the cathodic part of the cell containing the nickel

sulphate from the anodic part containing the mixture above mentioned. Experiments were made with lead, copper and zinc anodes. In the case of lead, he used in the anodic electrolyte mixture sodium chlorate as the salt dissolving the anode, and sodium sulphate, sodium bichlorate or sodium carbonate as the salt for precipitating the pigment. He similarly tried various mixtures in the anodic part of the cell with copper and zinc anodes, and in all cases he obtained good nickel at a moderate voltage and satisfactory ampère-hour efficiency; but in every case the anodic by-product was, for some reason, unsatisfactory. He therefore concluded that his original idea was not practical and had to be modified, and he now uses in the anodic part of the cell only the salt which dissolves the anode; but the precipitation of the insoluble salt is made outside of the cell. With lead anodes, he uses sodium chlorate in the anodic part of the cell, as before, for dissolving the anode; then lead chlorate is formed at the anode, and at the same time at the porous diaphragm on the surface looking towards the anode, and lead sulphate is obtained in the form of a thick layer. The lead chlorate thus obtained was changed outside of the cell into chromate, the electrolyte being thereby regenerated. The sulphate is changed into $PbCrO_4$, according to the equation $PbSO_4 + Na_2CrO_4 = PbCrO_4 + Na_2SO_4$, this reaction going on readily at ordinary temperature. The chlorate is very good, and, by varying additions of NaOH, various shades can be easily obtained. In the electrolysis the voltage varied between 3.5 and 4 volts, at a current density of 400 to 500 ampères per square meter and a temperature of 60° to 65° C. The ampère-hour efficiency of the nickel production was above 90 per cent. when no higher current density than 400 ampères per square meter was used. The nickel produced was good.

*Aluminium.*—That indefatiguable compiler, J. B. C. Kershaw, has a second article on the present position of the aluminium industry in the Lond. *Elec. Rev.*, April 10th. He gives some data concerning companies who have introduced aluminium, as a substitute for copper, for overhead electric conductors. The alloys of aluminium appear to have a promising future in motor-car construction work, and the manufacture of such alloys may become a flourishing sub-branch of the aluminium industry. "Builders of automobiles will, however have to recognize that aluminium and its alloys are not absolutely non-corrosive under all weather conditions, and they will be well advised if they cover all exposed surfaces with some protective varnish." The use of aluminium plates as a substitute for zinc, or in place of stone for lithographic work, is extending rapidly. Aluminium continues to be used largely as an addition to molten iron and steel at the moment of casting. The Goldschmidt process for producing high temperatures with powdered aluminium, mixed with iron oxide, appears to be widely used. The use of aluminium is also increasing in the form of the aluminium-magnetism alloy, "magnatism," which has a specific gravity of 2.52, is harder than pure aluminium and more suited for milling and screw-cutting purposes.

An article on the good forging properties of aluminium bronze is given by Sperry in the *Metal Ind.*, April

*Electrometallurgical Production of Iron and Steel.* The *Eng. and Min. Jour.*, April 4th, reprints an illustrated article from the London *Engineer* of March 13th, giving very brief descriptions of the following processes: Corbey, Harmet, Keller, Kjellin and Stassano. In general, in all the electric iron smelting processes the actual reduction of the ore is effected by the coke or other carbonaceous matter with which it is mixed, and an addition of lime or other fluxing compound is also required in order to obtain a slag that will become fluid at the temperature of the furnace; therefore the saving of fuel when using the electric furnace does not amount to much more than "1,050" pounds of coal per ton of iron or steel produced. (This does not agree with the figure below; either must be a misprint in the reprint from which this abstract is taken.) In the ordinary blast furnace, worked under the best conditions, one ton of iron can now be produced with 1,800 pounds of coke, of which 1,400 pounds represents that which is required theoretically for combining with the oxygen of the ferric oxide in the ore. If the average price of coke is $5.25 per ton, the actual saving effected by substituting electricity for coke as heating agent is only $2.50 per ton of iron produced. This sum would therefore have to cover the cost of the electric power, and also of the briquette making, required by most of the electric-furnace processes. From the figures given for the energy consumption in the above-mentioned processes, it is concluded that, even when no special crushing of the ore and mixing with the fluxing, reducing and binding materials is required as a preliminary to the operation of the electric-furnace processes, competition with the ordinary blast-furnace procedure is improbable. "When briquette making is first required, the position of the electric-furnace processes would appear to be hopeless." In countries where fuel is very expensive, water-power abundant and the necessary raw materials are found, these processes may have a limited field of usefulness, but their development, even under these favoring conditions, will be dependent upon the enforcement of high-tariff duties on imported iron and steel and upon a brisk home demand for these metals. In the iron-smelting industry of countries favored with a cheap supply of fuel the blast furnace will still easily hold its own. It will not be until coal and coke have become much more costly than they are to-day that the electric furnaces will displace the blast furnace—a type of furnace which is the most perfect fuel-consuming apparatus in general use, and is estimated to possess a thermal efficiency of over 70 per cent.

Beecker has an illustrated article on the Kjellin electric steel process in use at Gysinge, Sweden, in *L'Ind. Electrochimie* for March.

*Metallurgy.*—Among the other recent literature on electrometallurgy is a summary in *Glueckauf*, February 28th, by Schnabel, of the progress made in 1902 in various processes, especially in those for obtaining gold, silver, copper, lead, zinc and nickel from their ores. It consists mostly of brief descriptions taken either from articles in other journals or from patent specifications.

*Carbon Electrodes.*—A summary of notes on processes for the manufacture of carbon electrodes is given in the *Zeit. f. Elektrochemie*, March 26th. Besides an illustrated description of Acheson's well-known method of making graphite electrodes, the following notes on the method of making carbon electrodes in the German plant of Lessing are given. This manufacture has been taken up by those who make arc-lamp carbons, etc., the special feature of the new branch being the necessity of using very large machines. A single one of the hydraulic presses used for this purpose weighs 70,000 kg, and gives a total pressure of 2,000,000 kg, which, even for the largest cross sections used in practice, represents a pressure of 330 kg per square centimeter. The raw material is the retort carbon of gas works. By means of brushes all adherent impurities are carefully removed. For this purpose the original pieces, which often weigh 50 kg, are crushed into small pieces of hand size, and are then heated to 1,200° C. in the absence of air. The material is then pulverized into extremely fine powder and mixed with absolutely dry tar. It is then formed, pressed and left in the air for several days, in order to harden. The next step is to heat them in furnaces to 1,300 degrees. This is the most difficult operation, as the heating must be done slowly, in order to get the whole mass of the carbons to a uniform temperature and remove all the tar in the mass. It is recommended to spend about two weeks for the gradual heating of the carbons to the maximum temperature and for the cooling. The French company, Le Carbone, uses the Girard & Street process of making graphitized electrodes. Their furnace is designed for continuous operation. The carbon prisms pass through it from the top to the bottom, and are heated up to white heat by several

intense arcs. Their normal furnace consumes 10,000 ampères at 130 volts. The principle of the process is that each carbon in the arc zone serves as electrode for one or several arcs.

## THEORETICAL AND EXPERIMENTAL.

*Potassium from its Molten Hydroxide.*—It may be recalled by those who have followed the literature on the electrolysis of molten salts that Lorenz, of Zurich, has offered what seems to be a very plausible explanation or theory of the poor ampère-hour efficiency sometimes obtained, and, what is more interesting from a theoretical standpoint, of the fact that the voltage may then be even lower than the theoretical. His explanation is that the cathodic deposit remains in part suspended in the liquid, forming what he calls a mist, which, when it reaches the anode, acts as a depolarizer and forms the original compound again. Le Blanc and Brode have recently claimed that it was impossible to get metallic potassium from its hydroxide, notwithstanding that it is very simple to get sodium from its hydroxide. Lorenz and Clark, in this connection, refer, in the *Zeit f. Elektrochemie*, April 2d, to the theory of Lorenz, stating that this phenomenon is analogous to the vaporization phenomenon, and is dependent upon the vaporization of the metals at the temperature of the bath. For the theory of the deposition of metallic sodium or potassium from their molten hydroxides, it is of importance that the vapor tension of potassium is greater than that of sodium at the same temperature; the tendency for the deposited metal to redissolve and form metallic mist is therefore much greater for potassium than for sodium. According to Lorenz's theory, it is necessary for the production of metallic potassium from its molten hydroxide that the cathode is inclosed by a porous diaphragm, which serves to hold the potassium mist together. Experiments have fully confirmed this view. He uses as cathode an iron wire of 3 mm thickness, which passes through the top of a magnesite globe, the bottom of which is open. This globe is placed in the molten salt, and acts as a porous cup. After the electrolysis has been finished the globe is left for some time in the bath, which is cooled down, so that the open bottom of the globe is covered with a layer of solid hydroxide. The globe is then taken from the bath while it is still plastic; it is then placed in kerosene and allowed to cool to ordinary temperature. If the globe is then broken, it is found to be filled with solid potassium. In exactly the same way the authors electrolyzed molten barium hydroxide in order to get barium, but, after electrolysis, barium oxide, and not barium, was found in the globe. The authors assume that the deposited barium reacts at once with the barium hydroxide, perhaps according to the equation $Ba(OH)_2 + Ba = 2BaO + H_2$. Magnesite was found to be an excellent material for diaphragms for the electrolysis of molten hydroxide. It has already been used by Darling for this purpose. It is not suitable for the electrolysis of molten chlorides.

*Bipolar Electrodes, or Metallic Diaphragms.*—Bancroft, in a recent paper, gave the results of experiments made to study the behavior of a metal plate inserted in an electrolyte between the anode and the cathode, but not connected to either nor filling the whole cross section of the liquid. His paper was read before the American Electrochemical Society, and will be found abstracted elsewhere in this issue. It seems that Brochet and Barillet made quite similar researches, which are described by them in the *Zeit. f. Elektrochemie*, March 20th. In all their experiments the authors used copper sulphate as the electrolyte. In their first experiments they used platinum as anode and platinum as intermediary plate. Later they used for the latter a platinum plate coated with copper on the side towards the cathode, and finally they used a copper anode. The observations made in these different cases are described in detail, especially for the conditions under which the intermediary plate acts as a bipolar electrode or as an inert plate. The experimental results seem to be what would be expected from theory. Danneel, in an article on the same subject in the same journal, describes quite a number of similar experiments, and also gives some theoretical notes on these experiments of Brochet and Barillet. Among his own experiments is the following, in which he used copper plates as electrodes and copper sulphate as electrolyte. He built up an intermediary diaphragm of arc-lamp carbons, 7 cm long and 1 cm thick. They were piled up, and thus formed a 7 cm thick porous diaphragm, which sets up a very small resistance to the migration of ions, and, although it conducts metallically, it does not give rise to any chemical action at its terminals as long as the difference of potential between these terminals is not above a certain value; it is, at the same time, absolutely durable.

*Decomposition Curves of Copper-Salt Solutions.*—In the same journal, April 2d, Abel has a note on a recent paper of Miss Heiberg, who deduced decomposition curves of various copper salt solutions; in which curves the abcissas are the applied e. m. f's and the ordinates the currents. These show two sharp bends, one corresponding to the discharge of cupric ion to metallic copper, the second being 0.1 volt lower, and had been assumed by Heiberg to correspond to the discharge of cuprous ions to metallic copper. The present author suggests that it is more probable that it corresponds to the partial discharge of cupric ions to cuprous ions.

*Cathodic Deposition of Lead.*—In another note in the same issue Elbs and Rixon point to the fact that in the electrolysis of certain lead salts the lead is deposited on the cathode in two different forms, either as bright, thin crystals or as a sponge consisting of needles, with a dull luster. They then state that they have found that an electrolyte in which the lead at the cathode is deposited in the first form always begins to yield spongy lead from the moment when it contains fourvalent lead ions.

*Voltameters with Platinum Electrodes.*—Bartorelli has studied in detail the polarization and resistance of voltametric cells consisting of platinum electrodes dipping into a more or less concentrated solution of sulphuric acid, and describes his researches in the *Phys. Zeit.*, March 15th. He finds that as the current increases the polarization increases also, but not in proportion to it. At high currents a maximum is attained, and this maximum is maintained for all higher values. This result is of importance with regard to the ionic theory. For concentrations of 1, 5, 10 and 15 per cent. the maximum polarizations are attained with current densities of 50, 62, 75 and 100 milliampères per square centimeter, respectively, at the electrodes. The value of the maximum polarization varies from 2.7 to 2.9 volts from a concentration of 1 per cent. to a concentration of 15 per cent., and is therefore nearly constant. The conductivity shows a very similar behavior, attaining a maximum which appears to become a constant. In the case of platinum, as well as aluminium electrodes, the resistance at high values depends almost exclusively upon the surface of the electrodes. The variations of resistance, therefore, pertain to the surface of the electrodes, and may, therefore, be called resistances of transition. The article will be found abstracted briefly in the *Lond Elec.*, March 27th.

*Electrolytic Dissociation of Platinum by Means of Alternating Currents.*—Ryer has recently made an investigation of the dissolving of platinum in various electrolytes under the influence of either or both alternating and direct currents. The electrolyte was contained in a U tube, in one arm of which there were two electrodes connected to a source of sinusoidal alternating current. In the other arm there was a third electrode, which was the cathode in a direct-current circuit, one of the two electrodes in the other arm acting as anode in the direct current circuit. He first experimented with platinum in a sulphuric acid solution, containing two parts of acid to one part of water, and found that, under these conditions, the platinum is not dissolved by the alternating current alone as long as there is no oxidizing agent in the solution. It is dissolved, however, by the combined action of alternating and direct current, as above described. It is dissolved also by the

alternating current alone when an oxidizing agent, like chromic acid, or even oxygen, is present. Most of the other electrolytes which were investigated behaved in the same way as sulphuric acid. But in some electrolytes, like hydrochloric acid, sodium chloride, etc., in which one ion has a tendency to form a complex ion with platinum, alternating current alone dissolves platinum without the presence of oxidizing agents, but in these electrolytes the platinum is also dissolved under certain conditions by direct current alone. He assumes that the attack on the surface by alternating current is due to a formation of a very thin layer of oxide when the platinum is the anode, and to the subsequent reduction to a lower soluble oxide when the platinum is cathode. Passive iron behaves similarly to platinum, and he concludes by analogy that the hypothesis of the passivity of iron is due to a layer of oxide is not impossible. The original is in the *Zeit. f. Elektrochemie,* March 19th.

*Dielectric Constants of Liquids.*—An account of observations made by Tangl, extending over a wide range of temperature, is given in the *Ann. d. Phys.,* No. 4. As it has been found that the Clausius-Mossoti formula depends upon the temperature, the present author has investigated whether the formula could be used as an index of chemical change, more especially in view of the parallelism between the dielectric constant and the degree of dissociation indicated by Nernst. The results show that Nernst's method is available for temperatures ranging from 20 to 180 degrees in the case of benzol, toluol, xylol, carbon bisulphide and chloroform, and that ether can be followed right up to its critical temperatures (192 degrees). The first-named liquids show a practically linear decrease in the dielectric constant. Ether and chloroform show nearly the same course, but as the former approaches its critical temperature there is a rapid falling off. Ether also shows an anomaly in its dielectric constant at the critical temperature, being still much greater than the square of its refractive index for infinitely long waves. Of the substances enumerated, xylol is the only one which gives a constant value in the formula. In the other substances there is a decrease of from 5 to 17 per cent. between 0 degree and 200 degrees. An abstract may be found in the Lond. *Elec.,* April 3d.

*Electric Properties of Gaseous Mixtures.*—An experimental investigation of the effect of the electric "effluvium" upon gases has been made by Boury, and is briefly referred to in the Lond. *Elec.,* April 3d. The electric discharge, called by him the "effluvium," is incapable of changing the physical or chemical constitution of the gas through which it passes. It does not produce the explosion of an explosive mixture, nor does it produce an appreciable change in the pressure of the gas. He has also investigated the dielectric strength of mixtures of hydrogen with various other gases. At high pressures the critical field is sensibly a linear function of the pressure, independently of the thickness of the gaseous layer, whereas at low pressure the walls exert a complex disturbing action, either on their own account or through a gaseous layer condensed upon them. The author, therefore, confined his experiments to pressures above several millimeters of mercury. In one class of mixtures the critical field is the exact mean of the critical fields of the gases taken separately at the pressure of the mixture. Such mixtures are those of CO and $CO_2$, or CO and H, which do not act chemically upon each other. It is more remarkable that the same law holds good for a mixture of nitrogen protoxide and hydrogen. Another remarkable case, but in the other sense, is the decided reduction of the critical field in a mixture of hydrogen and carbon dioxide. The original is in the *Comptes. Rendus,* March 16th.

## PRIMARY AND SECONDARY BATTERIES.

*Measuring the Internal Resistance of a Battery.*—In all the ordinary methods of measuring the internal resistance of a battery there is an error, due to the running down of the cell. But this error may, it seems, be reduced to a minimum in the following two methods described by Oyres, which require no special apparatus, are easily worked and are accurate within 0.1 per cent. or less. The first method consists in comparing the potential difference between the poles of the given battery on open and on closed circuit by means of a potentiometer, as shown in the adjoining diagram, Fig. 1. The sum of the resistances $r_1 + r_2$ is held constant during the tests, say, at 15,000 ohms; L is a source of current, say, two Leclanche cells; S, a small adjustable resistance; G, a galvanometer; B, the cell to be tested; *r*, a resistance, and *a, b, c* mercury cups for making connections. If the resistance *r* is 5 ohms, then the resistance between A and b is known to be 5 ohms plus a small fraction of an ohm. The test consists of two steps. First, the resistance AD is so adjusted that on joining c to b by a thick copper bond there is no deflection of the galvanometer. Second, *a* is joined to *b*, and immediately afterwards to *c*, the resistance AD being adjusted so that, while AC has the old value, the drop in potential along AD equals that along Aa.

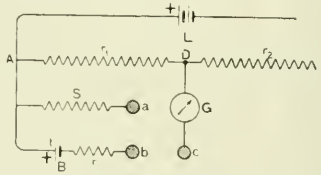



Fig. 1. Measuring the Internal Resistance of a Battery.

Then, if the cell did not run down, there could be no deflection of G. But in practice this is never attainable, and it is necessary to get the smallest possible deflection in the direction in which B alone would deflect G. From the two values of the resistance, AD in both cases, the internal resistance of B can easily be calculated (the final formula is not given in the original). The accuracy of the method depends upon the shortness of the interval between the short-circuiting (connection *ab*) and the connection to the galvanometer (connection *ac*). He adjusts this interval in a very simple manner by making the connections between *a, b* and *c* by a piece of thick copper wire, bent into three limbs, one of which fits into each mercury cup a, b, c. The limb fitting into c is cut about ½ cm shorter than the other two; then, on dropping the three arms into the cups, the cell is short-circuited automatically just before it is joined to the galvanometer. Further adjustment is possible by adjusting the level of the mercury in the cups. The

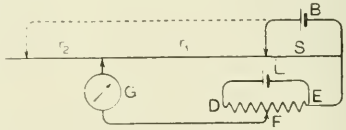



Fig. 2.—Measuring the Internal Resistance of a Battery.

second method consists in equating the drop in potential between the terminals of the cell, when short-circuited through a small resistance, to a known fraction of the potential difference between the terminals joined through a large resistance. The simplest form of connections is shown in Fig. 2, in which B is the cell under test, S the small resistance and $S + r_1 + r_2$ the large resistance. These two potential differences are equated by making an auxiliary (third) potential difference on a potentiometer equal to the first p.d., and then making the second p.d. equal to the third, as will be seen from the diagram. Results are given of the test of a small storage battery in series with about 5 ohms. The results of both methods agree with one another, and are certain within 0.1 per cent. Further details are given in the Lond. *Elec.,* April 17th.

*Galvanic Cells.*—Mugdan concludes his long article in the *Chem. Zeit.* April 1st and 15th. The galvanic cell, together with a motor, is, theoretically, the most perfect machine for

changing chemical energy into mechanical work, but in practice the case is different. Only those chemical reactions can be utilized in a galvanic cell in which ions take part, and therefore the number of chemical reactions which can be utilized in a cell is limited. In spite of its bad efficiency, the use of the steam engine is the cheapest method in practice. The two disadvantages of galvanic cells are that the available chemical reactions are expensive, and that there are losses in galvanic cells, although they are smaller than in engines. The author briefly discusses the cells used in practice, and makes some remarks on the use of aluminium as electrode. He then discusses carbon cells, and, after some theoretical remarks, mentions that from Nernst's calculations of the free energy corresponding to the process $C + O_2 = CO_2$, the e. m. f. of the ideal carbon cell would be about 1 volt. Experiments made to construct a practical carbon cell are then noticed. They are said to be very insignificant, as in none of the cells devised has it really been proved that the small electric energy given out was indeed due to the oxidation of the carbon. He then refers to some indirect ways of solving the problem, and mentions, for instance, the Daniell cell, in which the zinc sulphate which is formed may be regenerated by means of carbon into zinc and sulphuric acid; and in the same way the copper formed may be changed to copper sulphate by means of this sulphuric acid and air, so that the cell may be used in a cyclic process, in which it gives out energy, while only carbon and oxygen are consumed. But he remarks that this very uneconomical and complicated device can scarcely be considered as "a carbon cell." In summing up, the author states that a cell in which the oxidation of carbon renders work is quite possible, but the technical difficulties are enormous, especially the internal resistance, polarization, self discharge, impurities, the problem of diaphragms and, above all, the question of the cost of installing and maintaining. This latter point should be carefully taken into consideration.

*Storage Batteries.*—Among the other articles involving storage batteries are two which give some notes on the recent automobile exhibition in Agricultural Hall, in London, and on the German automobile exhibition in Berlin. Another is by Goetz, which is a continuation of his serial on the electric lighting of railroad cars. All three articles are in the *Centralblatt f. Accum.*, April 1st and 15th.

## GENERAL AND MISCELLANEOUS

*Electric Ore-Finding System.*—Until not very many years ago there were many believers in a mysterious rod, termed, we believe, the "divining rod," which had the remarkable property of pointing to places where underground sources of water or springs could be found. A description of something similar, and even more useful, as it shows where valuable ores can be found, is described in the Lond. *Elec.*, April 3d. It was devised by Dart and Williams, and was recently exhibited at the Telacve lead mines, in North Wales, England. It differs from the first mentioned in that it points out the location of something more valuable than water, and that it is based on what appear to be rational principles, instead of mysteries, and it is hoped that it may therefore turn out to be more useful. The method requires no expert knowledge to operate it. The transmitting apparatus consists of a large induction coil, the secondary of which is earthed and shunted by a condenser. A secondary battery is used to energize the induction coil, and the potential at the terminals of the secondary winding is about 30,000 to 40,000 volts. Earthing is effected by means of steel spikes, driven about 9 inches into the ground. Both the transmitter and receiver connections are shown in the adjoining diagrams. The principle of the system is expressed in the belief of the inventors that electric impulses or "waves" are radiated by the transmitter in ever-widening circles, and that therefore, under normal conditions, the time of maximum intensity—that is, a line on which they should obtain the loudest effects in a telephone receiver—will be found at right angles to a straight line joining the two transmitter terminals. When the receiver spikes are stuck in the ground in the immediate neighborhood of this line, and the receiver responses are found to be louder than at any other spot on a semi-circle drawn through this point, with its center midway between the two transmitter terminals, then it may be assumed that the conditions are normal, and that no metallic lode exists in the immediate neighborhood. But if the best effects

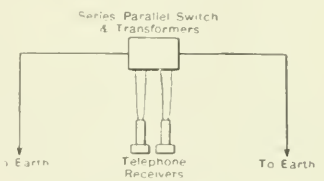



FIG. 1.—TRANSMITTER.




FIG. 2.—RECEIVER.

are not heard in the receiver when it is over or near this line of normal maximum intensity, but at a point some distance away, then it may be inferred, according to the inventors, that a metalliferous vein exists within no great distance, because it is assumed that the impulses or waves are diverted from their normal course by a metallic lode. By varying the position of the transmitter spikes, it is possible to throw the line of normal maximum intensity in any desired direction, which may be selected at random or from geological knowledge of the locality. The inventors claim that they have in one instance discovered a new vein of metal in an apparently worked-out mine, and that on recommencing work very successful results were obtained. Editorially, this journal says that it is somewhat difficult to see how the system could be used to determine with any degree of accuracy the depth, nature or quantity of the lode, and therefore to be able to say whether or not it would be worth attempting to recover. But if it will only locate the position of the ore, a great advantage will have been gained. The system is still in its early stage.

American Institute of Mining Engineers.—It has been announced that the meeting for July next in British Columbia, with an excursion to Alaska, has been rendered impracticable by the withdrawal on the part of the Canadian and American railroads of assurances previously given as to cars for the proposed trips. The Pullman Co. had been able to assure the Institute of ample cars for one way, but could not provide the equipment for the return journey. The reason for this step is the unprecedented demand for cars for the regular traffic. Applications and negotiations in every possible quarter have resulted in the conviction that it is impossible to secure even one special train for the journey to British Columbia and back. The abandonment of this trip is sadly regretted, because it is known that in many cases other plans for the summer have been given up for this excursion; and friends of the Institute in British Columbia and Alaska had in view elaborate entertainment, and committees have been actively engaged in arranging the details.

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl.

Electric Furnaces and Furnace Products.

*Method of Heating Material.* E. G. Acheson, Stamford Township, Canada, assignor to the Acheson Co., of Niagara Falls. Patent No. 723,031, March 24, 1903. Application filed September 26, 1902.

This invention relates to a method of conducting operations which are dependent upon definite temperature conditions. The specific instance to which the method is applied is the production of the so-called "white stuff," an amorphous compound, produced in the carborundum furnace at a temperature lower than that necessary for the formation of carborundum. The materials present in a carborundum furnace at the end of the run consist of the carbon core, the body of carborundum, a thin layer of "white stuff" and the undecomposed charge, in the order named, from the center outward. The temperature limits, between which this white stuff is formed, are comparatively narrow, being between 3,500 and 4,000 degrees, and the difference between the temperature required for the production of white stuff and the temperature at which it passes into carborundum does not exceed a few hundred degrees. The white stuff, on analysis, shows the following composition: Carbon, 37 per cent.; silicon, 59.1 per cent., leaving 3.6 per cent. for iron, aluminium, calcium and oxygen in undetermined amounts, the metals having been introduced through impurities contained in the charge. In order to convert the whole charge of a furnace into this white stuff, the furnace has to be so constructed that the temperature to which the charge is subjected does not run up to that temperature at which carborundum is formed, nor

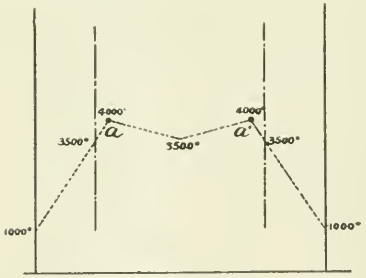



Fig. 1.—Diagram of distribution of temperature.

fall below that necessary for the production of white stuff. For this purpose Mr. Acheson provides several heat-distributing centers, the regions of maximum heat being so placed in relation to each other that the temperature of the intermediate minimum shall not be less than the inferior limit of the reaction. The sketch, Fig. 1, shows the distribution of temperature when two regions of maximum heat are employed. In a practical furnace, of course, the number of these regions may be indefinitely increased to suit the needs of the operation, the only condition being that they shall be so located that the intermediate minima afford sufficient heat for the accomplishment of the desired reaction. As an instance of application of the method on a practical scale, Mr. Acheson states that he has employed a furnace 48 inches long, 25 inches deep and 25 inches wide, filled with a charge of carbon and sand. Within the charge mixture were embodied four cores of granular carbon, each being 48 inches long and 2½ inches in diameter. This furnace was operated for twelve hours. The voltage throughout was about 80, the current at the moment of starting being 500 ampères, and increasing to 1,500 ampères within a few minutes, where it remained approximately constant to the end of the run. On opening the furnace it was found that the desired product, white stuff, had been formed, and that the reaction had involved all of the material confined within the cores and the material lying outside of the cores for a distance of 3 inches. Mr. Acheson states: "It is not sufficient for the operation of my method that a series of heating conductors be employed, nor does a series of conductors equally spaced and embedded in the charge constitute of itself an apparatus capable of carrying out my method. It is necessary that the resistance conductors or other devices for the application of heat to the mass of material be definitely spaced with relation to each other, at distances largely determined by the heat conductivity of the charge, the duration of the operation and the superior and inferior temperature limits of the operation. Under such conditions only will the temperature variations within the mass of material under treatment fall within the temperature limits of the operation. . . . My invention is not restricted to electric-furnace operations, nor to operations taking place at high temperatures, but is applicable in general to such processes as require for their most efficient conduct definite temperature conditions throughout the mass under treatment."

*Electric Furnace.* C. S. Bradley, New York, N. Y. Patent No. 723,643, March 24, 1903. Application filed June 19, 1900.

The furnace belongs to the rotary, continuously-working type of furnaces, and is applicable to the reduction or forma-

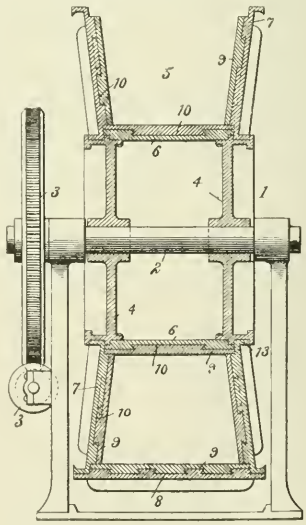



Fig. 2.—Bradley rotary furnace.

tion of refractory materials, but probably, as his former furnace of that type, is intended to be used for the production of calcium carbide. Such furnaces consist of a rotary wheel with a hollow rim, which serves as a receptacle for the charge. Electrodes dip into this rim at one point on its circumference, and there the formation of the product takes place. The product is carried away from the vicinity of the electrodes by the rotation of the wheel. In order to keep the fused material from spilling, plates are then fastened to the outside of the rim, which are removed when the material has sufficiently cooled down so as to make it possible to remove it. Furnaces of this type presented several disadvantages when worked on a

practical scale. When the wheel is made of cast iron, the outer portions of the charge are relied upon to protect the rim; and therefore it is not possible to apply heat enough to have the whole charge enter into reaction, with the result that a considerable portion of the charge is wasted. Still more waste is produced by the necessity of separating the unfused or partially-fused part of the charge from the fused mass after the latter has been taken out of the furnace. In order to overcome these difficulties, the furnace under consideration is constructed in the manner shown in cross section in Fig. 2. The wheel is mounted on a shaft 2, with driving gear 3. The annulus 5 is U shaped, and is made up of a series of interior plates 6, flange plates 7 and cover plates 8, for the purpose of holding the material, as stated above. In order to make it possible to subject the whole charge to the action of the current, a facing of graphite 9, of suitable thickness, is provided, which is dovetailed into the iron plates. As the lining material is somewhat soft, and might be injured when a charge is being removed, the flange plates are flared outwards, in order to facilitate the removal. It is claimed that the work may be carried on until the fusing has been continued throughout the mass right out to the lining. All the material in the furnace is reduced, no hewing off of material being necessary, and much labor is saved. It is not expressly stated in the specification whether two independent electrodes are to be used, as in the Horry type of furnace; or whether the carbide charge is to constitute one pole and a carbon electrode the other, as in the former Bradley furnace. It is obviously intended to cover the use of the improvement with both types.

*Electric Furnace.* Robert Winter, Berlin, Germany. Patent No. 724,099, March 31, 1903. Application filed August 7, 1901.

This furnace is intended for dental purposes. The heating plates, containing the electrically heated wires, often extend in these furnaces over the entire inner side of the furnace. In consequence of the very strong heat to which they are subjected, the plates change their structure and shape, become strongly bent and finally break. As the heating wires are quite immovably imbedded in these plates, the plates, when broken, do not allow them to contract when the furnace cools down, and consequently they break. To avoid this drawback, according to the present invention, the heating walls of the furnace are not constructed in the form of plates, but are built up of a number of single hollow rods containing the wires quite loosely, while they themselves rest freely with their ends in grooves provided in the heating space of the furnace. Between each two of such hollow rods preferably small spaces may be provided, so that the sides of the rods, as well as their front faces, can radiate the heat received from the incandescent wires. The length and thickness of the rods are so determined that they can freely expand in all directions.

*Electrical Smelting Apparatus.* R. L. Barnhart, Charleroi, Pa. Patent No. 724,778, April 7, 1903. Application filed May 14, 1902.

This is a furnace especially intended, according to the inventor, for the reduction of gold, silver and copper ores. In its construction the well known principle of compressing the pasty material which is to be treated into rods or bars, and using them in this manner as electrodes, between which an arc is sprung, is made use of. The apparatus consists essentially of two cylindrical drums, situated opposite each other with their small ends. They are provided with a hopper for the feeding in of the pasty material, and a screw rotates in the interior of each drum, forcing the material through a cylindrical head provided with passages, for the purpose of compressing it into the form of rods or bars. A box of firebrick is disposed between the two heads, possessing openings corresponding to those in the heads. Current connections are made to the two heads, and as the rods are forced out into the middle insulating firebrick chamber the arc is struck between them, and they are melted. The matte and slag produced drop through an opening in the bottom of the insulating firebrick box onto a rotating conveyor apron, formed of metallic screening. Spray pipes are arranged between the drums for the purpose of throwing sprays or jets of liquid flux on this screen, whereby, as the inventor says "the screen is kept in a fluxed condition. As the matte and slag fall on the screen, they are acted on by the flux, and the matte adheres to the screen, the slag being scraped off by a scraper. When the screen becomes sufficiently charged with matte, the screen should be taken off the machine and subjected to a refining process, while a new screen should be applied." The cost of the various operations of pulverizing, smelting by the arc, etc., as compared with the present metallurgical operations, does not seem to have troubled the inventor very much. The idea of spraying a "flux," composed of 10 pounds of sal ammoniac, 5 pounds of borax, 2 gallons of saturated solution of zinc chloride, 10 to 15 gallons of water and 1 to 2 pints of glycerine, on a molten material is certainly a novel one, though its efficacy may be doubted.

*Ore Separator.* H. G. Johnson and M. S. Howard, Waukon, Iowa. Patent No. 724,705, April 7, 1903. Application filed September 5, 1902.

The apparatus described in the specification is not an ore separator at all, but is intended as a contrivance for roasting ores by means of the heat furnished by the electric current. The apparatus is primarily designed for roasting copper ores, in order to change them from the sulphide into the sulphate, which is then treated by any of the ordinary metallurgical processes. It consists of a rotating conical shell, in the center of which there is arranged a tube concentric with the shell. The ore is fed from a hopper into the outer shell, which is provided with longitudinal scraping devices, for the purpose of agitating the ore and distributing it evenly. The ore travels by gravity down towards the larger end of the conical casing, and is there caught in pockets and elevated by the revolution of the casing into a second hopper, which delivers it into the inner tube. This tube is also provided with longitudinal devices for agitating the ore, and a longitudinal, perforated pipe is arranged in its center for the purpose of supplying air to the heated ore. The current travels through the inner tube and passes into the outer shell at the narrow part of the apparatus, and from there back to the dynamo.

APPARATUS AND PROCESSES FOR THE ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

*Art of Operating Electrolytic Cells.* E. A. Le Sueur, Sault Ste Marie, Canada. Patent No. 723,398, March 24, 1903. Application filed April 24, 1901.

This invention is designed to improve the efficiency of electrolyzers with porous diaphragms, and especially of electrolyzers used to decompose aqueous solutions of the alkali chlorides. The apparatus is a sort of Hargreaves apparatus with an asbestos diaphragm, which separates the anode from the cathode compartment. The cathode of wire netting is fastened to the diaphragm on the side towards the cathode compartment, and is therefore only in contact with the alkali chloride solution by means of the diaphragm. The level of the liquid is higher on the anode side than on the cathode side, with the result "that a tendency is set up to cause flow of the solution from the anode side to the cathode side of the diaphragm, and thereby oppose the tendency which always exists, for the products of decomposition in solution at the cathode to find their way into the anode compartment, to the serious prejudice of the cell's efficiency." It is stated further: "With a view to further minimizing the objectionable tendency just mentioned, I practice the invention, which is the subject of the present application, by adding water to the liquid contents of the cathode compartment, preferably in a continuous stream, the said water being preferably of a lower temperature than that existing in the anode compartment, and I allow it to displace from the said cathode compartment an equivalent volume of an

alkaline solution. The effect of said addition of water is two-fold. It dilutes the alkali solution in the cathode compartment, and thereby renders less objectionable the results arising from the diffusion of a given volume of said solution into the anode compartment. It also, by reducing the temperature of the cathode compartment, minimizes the diffusive powers of the liquid contents of said compartment, which powers rise with the temperature. I am aware that it has previously been proposed to add hot water or steam to the cathode compartment of cells, but the object aimed at and accomplished is quite different from mine, in that the amount of such addition has only been enough to make up for lack of passage of liquid from the anode compartment in quantity sufficient to dissolve to a strong solution the alkali formed on the cathode." The last paragraph is evidently intended to emphasize the difference between this method of operation and that of Hargreaves.

*Electrolytic Cell.* Rudolph Johanns, Brooklyn, N. Y. Patent No. 724,580, April 7, 1903. Application filed December 11, 1902.

The apparatus is intended for the electrolytic decomposition of sodium or potassium chloride solutions, and is shown in vertical transverse section in Fig. 3. The cell 1 is made of iron, and is lined with a non-conducting material 2, glass or cement being suitable for this purpose. The anodes 7 are bars of platinum or carbon, and are arranged in a direction at right

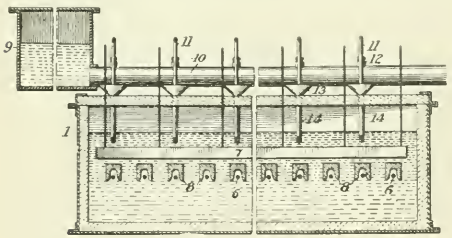



FIG. 3.—APPARATUS FOR ELECTROLYTIC ALKALI PRODUCTS.

angles to that of the cathodes. A series of rods 6, preferably of iron, serve as cathodes. Each cathode rod is surmounted and partially inclosed by a hood or inverted channel 8, of glass or cement. These hoods are intended for the purpose of collecting the hydrogen which is generated during electrolysis. The hydrogen is supposed to travel along them through the liquid, and be conducted into chambers which are situated at each end of the channels. The brine is fed from the supply tank 9 through pipes 10 and 11, funnel 13 and pipe 14 into the cell. The chief purpose of the several details of construction is to provide for the conduct of electrolysis with the minimum amount of agitation of the electrolyte. It is difficult to see, however, how this can be realized on a large scale in practice, as anyone who has seen the violent agitation of the electrolyte under the influence of a large current will be slow to believe that the hydrogen can be induced to religiously follow the path laid out for it in the drawing under consideration. Another drawback is the large increase in resistance, due to the covering of the cathodes.

*Cell for Electrolytic Bleaching Plant.* L. E. Lander, Warren, N. H. Patent No. 724,191, March 31, 1903. Application filed September 22, 1902.

This cell comprises a bag-like structure of asbestos or some other similar material which is sufficiently porous to admit of the liquid percolating through, and which is not attacked by the chlorine generated during electrolysis. This bag is supported by a cast-iron framework, with a substantially solid bottom and skeleton sides, constructed in the form of slats. The structure is covered with a cast-iron cover, lined with porcelain enamel. A carbon anode is suspended from the cover, and dips into the asbestos bag. The whole arrangement rests in a cast-iron dish, which serves as cathode, and in which the solution which seeps through the asbestos bag is collected.

*Composition of Matter for Electrolytic Decomposition.* Edward D. Kendall, New York, N. Y. Patent No. 724,107, March 31, 1903. Application filed September 17, 1902.

The inventor claims to have invented a new composition of matter for the electrolytic deposition of gold. The object of the invention is to obtain a solid composition of matter which, by mere solution in water, furnishes an electrolyte available for the electrolytic deposition of gold by means of an electric current of low electromotive force. He describes his mode of procedure as follows: "I first make gold trichloride in the customary way, by dissolving one part of gold in nitrohydrochloric acid and driving off excess of acid on the water bath. I dissolve this gold salt in a small quantity of water, and then slowly, with constant stirring, add this solution to, preferably, somewhat more than an equivalent quantity of potassium hydroxide—say, two parts, more or less, of potassium hydroxide dissolved in a small quantity of water. Then I add to the liquid and stir into the same a considerable quantity—say, 20 parts—of solid powdered potassium ferrocyanide, finally evaporating the whole to dryness on the water bath with constant stirring. The resulting solid product is my said composition of matter, which, with or without further addition of potassium ferrocyanide, for the purpose of increasing the electric conductivity of any otherwise very dilute solutions of the said composition, and with or without the addition of common salt or any other salt for the same purpose, I generally grind to powder and put into bottles that should be well stoppered. The proportionate quantity of water to be used in forming an electrolyte by solution of my above-described composition of matter, of course, may vary within wide limits."

*Cathode.* C. J. Henry, Perth Amboy, N. J. Patent No. 724,862, April 7, 1903. Application filed August 6, 1902.

The invention is intended to provide a cathode plate for the deposition of metals of simple construction, allowing the metallic sheet deposited on it to be readily removed, and preventing the deposition of metal on the edge of the plate. This object is attained by a special construction, forming the central portion of the plate upon which the deposit is to be received with a smooth and polished surface. A channel is provided all around this middle portion on both sides of the plate, with perforations at determined intervals. An insulating material, such as putty, is forced into the channel on one side, and, passing through the perforations, will fill up also the channel on the other side. The surface of the putty is then scraped until it is flush with the metallic portion of the plate. After the insulating material has hardened, the area destined to receive the metallic deposit is covered with any of the well-known materials to prevent too close adhesion. After electrolysis a corner of the deposited sheet may be raised, and the sheet stripped off. The insulating material prevents any deposit on the edge of the plate.

## Storage Batteries.

*Electrode for Storage Batteries.* T. A. Edison, Llewellyn Park, N. J. Patent No. 723,449, March 24, 1903. Application filed November 28, 1902.

This specification describes an improvement in electrodes for Mr. Edison's nickel-iron storage cells. Those electrodes are formed of plates with suitable openings, into which are crimped pockets or receptacles, intended to hold the active material. It was found that the active material, when subjected to a charging current, tended to bulge at the center of the pockets, and the plates could, therefore, not be closely placed together, as was desirable. This objection is overcome in the present patent by concaving the pockets by means of dies, so that when any swelling takes place it will not objectionally bulge the pockets. The best results are said to be obtained when two

sets of dies are employed—one for effecting the crimping and concaving of the pockets and one for effecting the corrugating. By transversely corrugating the exposed surfaces of the pockets the strength of the latter is very considerably increased, and thus the use of a lighter sheet metal is permissible. The dies apply pressure to all the pockets of a plate at the same time. Fig. 4 represents a plan view of one of the grids, showing one pocket in position.

*Reversible Galvanic Battery.* T. A. Edison, Llewellyn Park, N. J. Patent No. 723,450, March 24, 1903. Application filed November 28, 1902.

In the present application Mr. Edison claims mercury, or a combination of mercury and one or more other readily-reducible metals, such as a combination of mercury and copper, as a suitable material for addition to the oxidizable active material of a reversible galvanic battery. He states that mercury, when employed in connection with copper for such addition, preserves the surface of the copper, so that the use of flake graphite can be dispensed with and a better contact be effected between the particles of active material. The cell is also able to sustain a high voltage during the entire period of discharge. The mode of preparation is as follows: To the finely-divided iron, generally in a moist condition, there is added a sufficient quantity of ammoniated copper and of

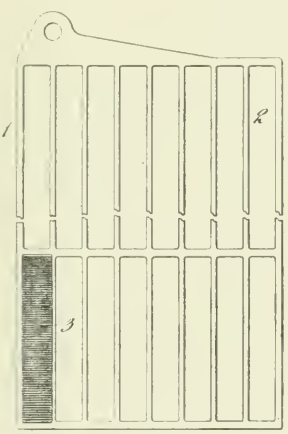



FIG. 4.—EDISON BATTERY ELECTRODE.

precipitated oxide of mercury, in order to obtain as final product a mixture composed of 64 per cent. iron, 30 per cent. of copper and 6 per cent. of mercury. The addition of ammoniated copper and oxide of mercury to the electrolytically-active iron results in the copper and mercury being immediately reduced to the metallic state by the reducing action of the iron, a portion of whose particles become oxidized, while at the same time the particles of metallic copper will be coated with an amalgam of mercury. In the reaction ammonia is liberated as a gas. As a result of this treatment the exterior of each active iron particle will be coated with a porous envelope of amalgamated copper in extremely finely-divided form, mixed with a small proportion of iron oxide. This mixture may be immediately molded into briquettes and used in a battery.

*Storage Battery.* J. B. Entz, Philadelphia, Pa. Patent No. 723,451, March 24, 1903. Application filed August 28, 1900.

The object of the invention is to provide a storage-battery element, which consists of a plate having a hook-like terminal, that extends opposite the face of the plate and, in conjunction with the wall of the containing jar, serves the double function of a separator and connector.

*Armored Element for Electric Batteries.* E. A. Sperry, Cleveland, Ohio. Patent No. 723,326, March 24, 1903. Application filed May 25, 1901.

The present invention aims at overcoming the disadvantages arising from the disintegration, abrasion and peeling off of the active material in storage-battery electrodes. The inventor proposes to provide a tough armor of an inert fabric, entirely covering the face of the electrode, preferably in an unbroken web. The fabric is made integral with the electrode by being embedded in the active material. The fabric is preferably made of nitrocellulose or pyroxylin, suitably prepared so as to retain as far as possible the strength of the original fibers. The active material, which is preferably employed in the formation of the armored plate, is a material which at some stage in its operation is plastic or can be made plastic, so that the fabric, when applied by pressure or otherwise, may be thoroughly incorporated with the material. An electrode thus constructed will be found to resist the washing and abrasive action of the constantly-moving electrolyte, and at the same time the armor is so porous that the gases have free passage.

*Storage Battery.* E. A. Sperry, Cleveland, Ohio. Patent No. 723,327. Application filed August 12, 1901.

This invention relates to the manufacture of hard positive plates for storage batteries, and has for its object to increase the hardness and density of such plates without interfering with the action of the electrolyte on the active material. Finely-divided lead is used as the active material, and a particular menstruum is employed for the purpose of moistening the active material to form the plastic mass, the combination of the menstruum with the metallic lead having the effect of rendering the positive plates denser, and therefore better able to withstand the disintegrating influences to which they are subjected. The menstruum consists of distilled water, to which is added ammonium hydroxide. It is stated that one part of hydroxide to two or three parts of water gives satisfactory results. The dry, powdered substance, which forms the body of the element, and which may by preference be a composition of metallic lead and ammonium sulphate, is thoroughly mixed with the above menstruum, and the plastic mass thus prepared is applied to the grid, which is then dried out under very high pressure.

*Storage Battery.* E. A. Sperry, Cleveland, Ohio. Patent No. 723,328, March 24, 1903. Application filed August 12, 1901.

The present invention is for the same purpose as the preceding, namely, the hardening of the active material. The menstruum in this case is an alkali metal salt, preferably chemically pure ammonium sulphate, to which is added a catalytic agent, preferably a small quantity of alizarine, about $\frac{8}{100}$ of 1 per cent. The alizarine is said to apparently promote the rapidity of the combination of the ammonium sulphate with the lead in the moistened mixture, after the manner of a catalytic agent.

*Connector for Accumulator Plates.* G. A. Washburn, Cleveland, Ohio. Patent No. 723,701, March 24, 1903. Application filed, divided, October 6, 1902.

This invention relates to connectors for positive and negative plates in storage batteries. It is claimed: "As a new article of manufacture, a connector, comprising a deep, flat member, disposed longitudinally above the adjacent edges of two adjacent cells, and having downward extensions lying against the walls of the said adjacent cells, said downward extensions being adapted to connect with the plates of said cells."

*Method of Producing Storage-Battery Plates.* W. Gardiner, Chicago, Ill. Patent No. 724,387, March 31, 1903. Application filed December 13, 1900.

The object of this invention is to hasten the time and cheapen the process necessary to convert metallic lead plates into storage-battery electrodes. The process consists of three steps. The plates are first oxidized in a solution composed of 10 per cent sulphuric acid, to each gallon of which 5 ounces of

sulphate of aluminium, 5 ounces of nitrate of ammonia and 1 ounce of oxalic acid have been added. A small amount of tartaric acid may also be added. To convert the oxide of lead into spongy lead, the plates are then removed and placed in an electrolyte, consisting of a solution of sulphuric acid, to each gallon of which are added 3 ounces of tartaric acid and 5 ounces of sulphate of magnesia. For the purpose of causing the mass of spongy lead formed by this treatment to adhere more tenaciously to the metal support, the plates are put into a solution of 15 ounces of sulphite of soda and 8 ounces of sulphide of ammonium, dissolved in a gallon of water. The plates should be subjected to the action of the current in this solution for twelve to fifteen hours. The plates should then be removed, washed and finally charged in a sulphuric acid solution having a specific gravity of about 1.2, when they will be ready for commercial service. The third solution may also be composed of water and any soluble sulphur compound having a lower degree of oxidation than sulphuric acid; for example, any of the soluble alkaline sulphides or sulphites, either singly or in combination.

*Storage Battery.* W. Gardiner, Chicago, Ill., and J. R. McMillan, Menominee, Wis. Patent No. 725,067, April 14, 1903. Application filed January 31, 1902.

This cell consists of tubular electrodes, the positive fitting into the negative, which itself is contained in a cell jar. The negative electrode consists of a perforated shell of chemically-formed sheet lead, fitting about a similarly-perforated shell of hard rubber. The positive electrode of active material is inclosed in a lining of canvas, surrounded by a closely-perforated shell of hard rubber. The upper end of the shell is sealed by wax or a similar material.

*Storage Battery.* J. M. Allen, St. Louis, Mo. Patent No. 723,804, March 31, 1903. Application filed July 21, 1902.

The essential feature of the invention, according to the inventor, is the construction of the plates, which he has found, from practical experience, will prevent them from buckling. The plates are constructed in the shape of long and narrow rectangular boxes, with thin walls. The positive pole plates are filled with oxide of lead, and the negative plates with carbonate of lead. And after the plates have been filled and put into the cell, they are submerged in sulphuric acid. The acid enters at the open top of the box-like structures, and is absorbed by the active material. The walls of the battery plates are unperforated.

*Process of Making Electric Accumulator Plates.* J. J. H. Hunte, Berlin, Germany. Patent No. 724,012, March 31, 1903. Application filed April 15, 1902.

According to this invention, lead plates are subjected to the action of chlorine and oxygen acting in combination, the gases being preferably electrolytically evolved from solutions of certain salts and oxidizing agents, hypochlorites usually being formed at the same time. As an example of a suitable electrolyte may be mentioned a solution of sulphate of soda, in which are dissolved various percentages of chlorides, such as sodium chloride, chlorates, as potassium chlorate and permanganates or sulphate of manganese, which will form a permanganate at the anode. When the above-described action takes place in solutions which show a feeble alkaline reaction, where the plate to be treated forms the anode, the duration of the treatment can be regulated to vary between ten and twelve hours and three to four days, the necessary duration depending upon the concentration, temperature and current density. After this preliminary treatment the plates are removed and connected as cathodes in the same solution. At the end of the second treatment they are found to consist of very porous layers of reduced lead, mixed with some lower oxides of lead, the whole being very firmly attached to the plates and entirely free from chlorides and chlorine. After the second treatment the plates are washed in running water, and connected as anodes in cells containing dilute sulphuric acid.

## CURRENT NOTES.

Electrochemical Society.—At the meeting of the Board of Directors of the American Electrochemical Society, held at New York City, on April 16th, the following-named gentlemen were elected members of the Society: H. O. Havemeyer, Jr., New York; Edward Park, Larchmont, N. Y.; Alexander Dick, London, England; F. C. McMillin, Cleveland, Ohio; A. S. Ferry, Lafayette, Ind.; Samuel F. Hall, Niagara Falls, N. Y.; J. E. Mills, Chapel Hill, N. C., and Virgil Coblentz, New York City.

Platinum Robberies.—Messrs. Eimer & Amend, of New York City, send us the following note: "Within the last four months an individual well acquainted with the conditions of chemical laboratories of manufacturing plants, especially iron and steel works, is plundering the chemical laboratories in Virginia, West Virginia, and now Ohio, of their platinum ware. We have had over a dozen such robberies reported within the last four months, and the way the thief goes about it clearly shows that he must have been a former iron chemist, thoroughly acquainted with the conditions of the chemical laboratories in the district mentioned. From what we learn, he is now traveling up the Ohio River, getting into Pennsylvania, and a great service can be done by your valuable medium, if you make these facts known, to put the chemists of iron, cement and steel, etc., works throughout the central United States on their guard against him."

Faraday Society.—The Society of Electrochemists and Metallurgists, which was recently founded in London, as noticed in the March issue of Electrochemical Industry, page 249, has assumed the name "Faraday Society." In our list of members of council the name of Dr. F. M. Perkins was omitted. Dr. Perkins has been appointed treasurer of the Society.

Aluminium Patent Suits.—By a decision of Judge Taft, rendered in 1893, in a suit of the Pittsburg Reduction Co. *vs.* the Cowles Electric Smelting and Aluminum Co., the latter company were enjoined from the manufacture of aluminium. By a recent decision of Judge Wing, this old case has been reopened for the introduction of new testimony and reargument on its merits. The other case between the Cowles Co. and the Pittsburg Reduction Co., wherein the former company is sueing the latter for infringement of the Bradley patent, was argued in New York on April 7th, before Judges Wallace, Cox and La Comb. Messrs E. N. Dickerson and Fred. H. Betts were the attorneys for the Cowles Co.; Messrs. Thomas W. Bakwell, Thomas B. Kerr, George H. Christy and Fred. P. Fish for the Pittsburg Reduction Co.

Erratum.—The authors of the paper on the "Equipment of an Electrometallurgical Laboratory," published in our March issue, on page 241, are R. S. Hutton and J. E. Petavel. By a typographical error the name of the last-named gentleman, who is well known by his investigations in various fields of physics, and especially by his researches on standards of light, had been printed Tetavel, instead of Petavel.

## *Correspondence.*

### ELECTRIC FURNACE PROCESSES FOR MAKING IRON AND STEEL.

To the Editor of Electrochemical Industry.

Sir:—In your last issue you have an article by Mr. Louis Simpson on "The Electric Reduction of Iron Ores and the Conversion of Iron into Steel in the Electric Furnace." With the sentiments and generalities therein laid down I am not concerning myself, except wherein he says, "Few of those who have written on this question have published statements that would appeal to the practical manufacturer; that is to say, those who have made it their business to know something about the cost of power production, of electricity and steel making." Further, "One expert condemned employing

hydraulic power wherewith to generate electric power, and claims that electricity can be generated from the combustion of (good) soft coal at a price that will put 'water-power in the shade.' This expert claims that 500 kilowatt hours can be produced by the combustion *under a steam boiler* of 1,000 pounds of soft coal."

He says further "that it is unnecessary to point out that up to date it has been impossible, under ordinary continuous working conditions to produce 500 kilowatt hours by the consumption of 1,000 pounds of any kind or quality of coal, burned under any kind of steam boiler."

These various quotations from the article refer to statements that I have made. I have stated and reiterate that I melt and partially reduce a ton of iron with less than 500 kilowatt hours. I have stated and say now that any good steam-engine builder will gladly take contracts for engines of large unit, guaranteeing to produce a kilowatt hour on 2 pounds of good coal.

In this connection a reference to the April number of *Power*, page 203, recites a test by countrymen of Mr. Simpson's of a small unit (only 300 horse-power), in which the consumption was 15 pounds of steam per kilowatt hour. And it would be a bad boiler or bad coal, or a combination of both, that would not make 15 pounds of steam with 2 pounds of coal.

I have never "condemned the use of hydraulic power." Far from it. But I do condemn hydraulic power *at a price in excess* of what power can be made for by other means. Mr. Simpson also says, "The commercial practicability of the electric process (of iron reduction?) is a question of such complex character that it is difficult for an expert of any one of the several branches of science interested to form a correct judgment upon the question as a whole unless he is posted in all the other branches; and, further, unless he has considerable knowledge of the commercial end of the question. It is not sufficient that this question should be considered by an electrochemist, nor by a hydraulic, civil, mechanical or electrical engineer. It is not sufficient that it should be considered by a metallurgist. It is necessary that the question should be considered by a man of experience in the market for which the steel made by the electric process is intended."

In other words, the man who buys and sells the certain grade of steel is to pass upon the electrochemical, hydraulic, civil, mechanical and electrical problems involved. My own idea of such an individual is that when he is competent to do this he will do something other than "sell steel." He would be hiding his talents too effectually by merely "selling steel."

But is it not to be conceived that, under our American system of specializing, one man may be so wedded to one line of work that he may know the hydraulic, mechanical, electrical, etc., sciences *as applied to his specialty*, so that he may have some right to speak with authority upon any and every question of science and practice as applied to his art?

MARCUS RUTHENBURG.

Philadelphia, Pa.

## AMERICAN ELECTROCHEMICAL SOCIETY ELECTION.

TO THE EDITOR OF ELECTROCHEMICAL INDUSTRY.

SIR: Now that "the smoke of the battle" has cleared away from the election of the Electrochemical Society, I desire to comment upon the letters concerning it in your issue of March, and especially upon the views set forth in the letter of the Niagara Falls members.

I voted for Professor Richards as president, and think the time is (as suggested in your March number by Mr. Hering) too early for a change in officers. But it should be understood that every member of the society is eligible for any office in it. It is a reflection of the gravest character on the integrity of a member of the society to assume that he would use his official position in it to advance his business interests at the expense of his fellow-members. Such an idea is fraught with danger, and if the society is to be "rent into factions" the sooner it is dissolved the better. It has no reason for being except to furnish a common meeting ground, free from local jealousies, with absolutely courteous and fair discussion.

The American Institute of Electrical Engineers has had presidents from all of the great electrical industries. I have never heard it suggested that these gentlemen have favored the Westinghouse Co., the General Electric Co. or other interests with which they are affiliated in any official action. Such a suggestion would be resented I am sure, and would make the suggester ridiculous.

Let us have peace. When any gentleman is named for an officer of our Society, let us vote for him or against him on the ground of his personal fitness or want of it, or our personal preferences. But, unless we know the contrary to be a fact, may we not assume that our members are honorable gentlemen? It was wholly unworthy of any members to make a contrary suggestion. No one would for a moment believe it applicable to any one of them.

Yours very truly,

T. J. JOHNSTON.

New York.

[We gladly join Mr. Johnston in the hope that there will be peace. We do not think, however, that in any of the letters published in our March issue the assumption has been expressed that any member of the Society would use his official position in it to advance his business interests at the expense of his fellow-members. A careful perusal of the letters in our March issue will, we think, sustain our view. While we have gladly opened our correspondence columns, without partiality, to all parties concerned, we would not have permitted a personal attack to be made therein. We consider this discussion herewith closed.—ED.]

## THE CASCADE WATER, POWER AND LIGHT CO., CASCADE, B. C., CANADA.

BY W. G. MCCONNON.

The hydroelectric plant of the Cascade Water, Power and Light Co., situated at Cascade, B. C., and owned by the London and British Columbia Goldfields Co., Ltd., has recently been completed, representing an investment, in round numbers, of $500,000. Cascade is a small town on the Kettle River, 12 miles east of the town of Grand Forks, and about 30 miles directly west from Rossland, B. C. Flowing from the west, the Kettle River descends 120 feet in passing through a half mile of narrow, rocky gorge in a series of rapids and falls. For the utilization of this natural power the Cascade Water, Power and Light Co. have built a large dam, waterway, pipe line, power house and transmission line from Cascade to Phœnix, where the largest and most productive copper mines in the "Boundary District" are situated.

The dam, placed just above the entrance to the gorge, is of timber cribwork, with a 40 foot base and 24 foot top. The mid section is 50 feet high, tapering to 25 feet at the sides, while the total length is 400 feet. This is built on a solid rock bed, to which the foundation timbers are bolted, and filled with 10,000 cubic yards of rock. This dam raises the water 30 feet above the natural level, giving an effective head at low water of 150 feet. The permanent water level is 10 feet below the top of the dam, being controlled during high water by 12 sluiceways, which can be opened to 12 feet below the natural river level, giving a passway of about 2,000 square feet. These sluices are closed by means of 12 x 12-inch squared timbers in grooves, operated by a traveling winch running on a track over the top of the dam.

From dam to power house the water first passes through a 225-foot open-rock cut, from which it enters a tunnel driven through 410 feet of solid rock, passing under the track of the Canadian Pacific Railway; and then into another open-rock cut 500 feet in length, at the end of which the bulkheads and controlling gates are located. These cuts and tunnel, repre-

senting an excavation of about 35,000 cubic yards of rock, are of dimensions liberal enough to avoid any appreciable loss of head, delivering the water with a head almost equal to that at the dam level.

From the gates the water is conveyed through a wooden pipe, 7 feet in diameter, for about 1,400 feet. This pipe is constructed of Oregon fir tongued and grooved staves, 2¾ x 7 inches, cut in circular segments and machined to the radius of the pipe. The staves are hooped at 12-inch intervals with ¾-inch round steel bands, with cast-iron connecting shoes for clamping. Provisions have been made for the installation of a similar and additional pipe.

From the stave pipe the water is carried through 250 feet of circular steel pipe, 7 feet diameter, resting on concrete piers

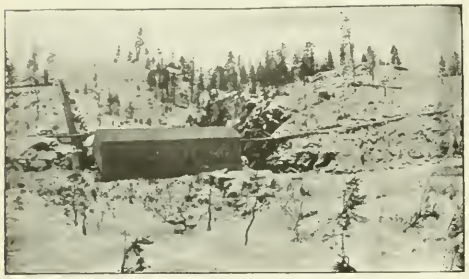


FIG. 1.—EXTERIOR OF POWER HOUSE, SHOWING STAND PIPE.

and anchored into solid rock to avoid end thrust. Where this pipe passes alongside of the power house three 4-foot pipes and one 2-foot pipe are taken off below the floor level of the power house to supply three 36-inch turbines for generators and two 12-inch turbines for exciters.

Fig. 1 is a general view of the power house, showing the stand pipe at the junction of the stave and steel pipes. This stand pipe relieves the pipe line from excessive water-ram strains, and incidentally voids any air taken into the pipes.

About 10,000 cubic yards of rock were removed for the site of the power house in a natural bay at the foot of the falls. This building is of substantial fire-proof construction, 150 x 50

FIG. 2.—INTERIOR OF POWER HOUSE, SHOWING GENERATORS.

feet, with stone foundation 22 feet deep on the lower side and brick walls 30 feet above floor level, the height to peak of roof being 45 feet. It has been designed with a view to lengthening it when required.

Fig. 2 shows the interior of the power house and the generating plant. The three generators are standard Westinghouse three-phase, two-bearing, direct-coupled, 2,200-volt, 750 kilowatts at 80 per cent. power factor, or 940 kilowatts at 100 per cent. power factor, 60 cycles per second, 300 revolutions per minute. The two exciters, each capable of exciting all three generators at one time, are 45-kilowatt, 120-volt, shunt-wound dynamos, self-contained, two-bearing type, direct coupled to independent turbines, with 500 revolutions per minute. The turbines are made by the S. Morgan Smith Co., York, Pa., and the governors, the Escher-Wyss make, from Switzerland.

Fig. 3 shows the transformers, nine in all, three in each bank, which are of the standard Westinghouse self-cooling, oil-insulated type, having a capacity of 250 kilowatts at 80 per cent. power factor, or 312½ kilowatts at 100 per cent. power factor, "star" connection, and wound for a ratio of 2,000 to 20,000 volts on both high and low-tension windings, with full-load efficiency of 97.6 per cent. As the taps are brought out near the neutral point, which is grounded, it is impossible to maintain a dangerous voltage in the auxiliary circuit.

The current from the high-tension side of the transformers is carried to a row of high-tension fused circuit breakers, situated alongside of the building, behind the main switchboard. The switches are of the well-known Westinghouse type, placed on independent marble slabs, with marble barriers between. The current leaving these switches enters a high-tension bus, and is carried to the line switches at the rear of the building. These line switches are grouped switches, opening all three wires at the same time. Each switch is furnished with a time-limit tripping device and reversed current-tripping coils, so that overloads can be carried for a period of from one to ten seconds, as the local conditions call for; or either line can be cut out automatically in case of trouble.

The switchboard for the low-pressure side consists of seven

FIG. 3.—INTERIOR OF POWER HOUSE, SHOWING TRANSFORMERS.

panels of blue Vermont marble, one panel for each generator, one for the two exciters and a feeder panel for each group of transformers. The six lightning arresters, located just above the switchboard, in the gable of the roof, are the "low equivalent" style of the Westinghouse Electric and Mfg. Co., giving protection against lightning discharges for transmission at 20,000 volts.

A right of way 132 feet wide is cleared, and transmission lines erected from Cascade, via Grand Forks, to Phœnix, a distance slightly over 21 miles.

The high-tension circuit consists of two separate three-phase transmission lines, each carrying three No. 3. B. & S. copper wires, with room on each line for another circuit. Throughout it is one of the most substantial and best-constructed lines in the Dominion. The poles are heavy cedar, and on tangents are spaced not over 100 feet apart; on curves at less distances, in some cases as low as 50 feet. No angles are turned, but all changes in direction of line made with easy curves. No side or head guys have been used, except at extra heavy spans across rivers, etc.

The work on this line, as well as all construction of the plant, is a decided credit to the company's local engineer, Mr. Wm. Anderson, who has designed and executed the work.

A three-mile feeder is taken off at Grand Forks, 12 miles

from Cascade, to the Granby Smelter of the Granby Mining and Smelting Co., where current is used for driving Westinghouse induction motors of sizes ranging from 3 to 700 horse-power, and of an aggregate capacity of 2,400 horse-power.

The sub-station at Phœnix is located at an altitude of about 3,500 feet above the power house. The building is of brick, with one end left for future extension, and contains the transformers, line switches, fused circuit breakers, switchboards, etc., substantially duplicating those at the power house. For the immediate present this sub-station will be called upon to supply current for two 700 horse-power Westinghouse, type "C," motors for driving two large compressors, a 100 horse-power motor for stone crusher and a 150 horse-power motor for hoist, as well as furnishing the current for lighting the town of Phœnix.

The Cascade Water, Power and Light Co. estimate that they will have a supply at low water for about 6,200 horse-power. This will enable the doubling of the present output. All the plans were made and carried out with the view of extending the plant to its full capacity, and, from present indications, it would seem that the company will have a demand for all the power they can furnish.

## EXHIBIT OF ELECTROCHEMICAL APPARATUS.

During the recent convention of the American Electrochemical Society, in New York City, Messrs. Eimer & Amend had arranged a very fine and interesting exhibit of apparatus used for electrochemical work. In the first place, we have to mention an extended exhibit of electric furnaces. Besides those illustrated in our November issue (page 112) and in our April issue (page 207), there were exhibited electric tube furnaces according to Heraeus, with special rheostats for the same; electric melting furnaces according to Borchers, for 100 to 300 ampères at 60 to 70 volts; electric demonstration furnaces according to Moissan, but in an improved form, larger and more accessible than in the old form, for 100 ampères at 50 to 60 volts; electric crucible furnaces according to Howe.

A carbon-determining apparatus, devised by Geo. O. Seward, chemist of the Willson Aluminum Co., was also shown. A detailed description of this very interesting apparatus will be given in our next issue, in which we intend to describe also the chemical apparatus (crucibles, tubes and flasks), blown and drawn, of molten quartz, which are the latest achievement in laboratory utensils.

Among the various other apparatuses exhibited there were polariscopes, various types of pyrometers, laboratory heating appliances, etc. There were also exhibits of electrically made chemicals, metals and alloys, of Kahlbaum's chemically-pure reagents for quantitative work, etc.

## CONVERTING DIRECT CURRENT FROM LIGHTING AND POWER CIRCUITS TO THE LOW VOLTAGE REQUIRED FOR ELECTROLYTIC WORK.

The rapid extension of both experimental and commercial electrochemical work has brought out the need of a motor generator, which, while receiving power from lighting or, comparatively speaking high potential power plants, yet delivers power at the low voltage and high current rate required for such work. It is evident that there is a great field for a reliable, light and inexpensive machine of this kind. Electric light and power for driving machines have been introduced in the past, or are now being introduced in all workshops, and it is quite clear that if electric current is wanted at the same time for electrochemical work it would be preferable to take it from the same mains.

The obstacle has been that for light and power the lowest voltage which has been used was about 100, while for electrolytic work heavy currents at a lower voltage are required. It is well known that while the voltage of alternating current may be easily changed by means of stationary transformers, which require practically no attendance, this is impossible for direct current. It can be proven that to convert direct current from one voltage to another voltage, revolving machinery is absolutely necessary.

The problem in this case was, therefore, the design of a light, inexpensive and absolutely reliable machine, capable of running on any of the ordinary constant potential direct circuits, and delivering current at any voltage from zero up to 5 volts (or more if desired) and of 50, 100, 200 and 500 ampères or higher, depending upon the size of the machine. Such a

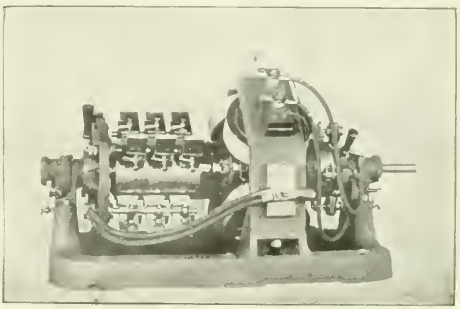


FIG. 1.—2.5 KW MACHINE.

machine furnishes a means of obtaining at any time heavy currents at low voltages, always under perfect control, and so economically that any ordinary lighting plant can furnish the power without difficulty. Such a machine, when used, for instance, in an electroplating establishment, would considerably reduce the cost of operation. At present the current for the electroplating baths is generally taken from a separate

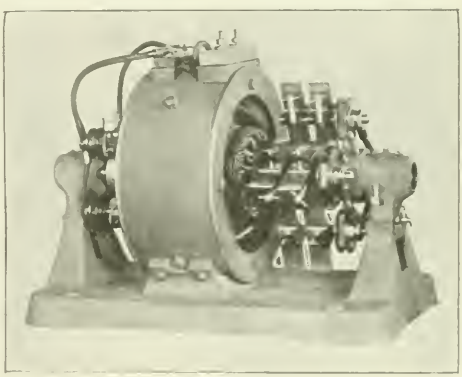


FIG. 2.—1 KW MACHINE.

source of current (a special electroplating dynamo, or batteries, etc.), and not from the electric light mains. If such a machine as will be described below would be installed, all the electric current could be taken from the lighting circuit. The cost of operation would be reduced, and the whole operation would become simpler and less troublesome. The same remarks hold, of course, good for any electrically-lighted plant in which an electrolytic process is used. In the following we describe a machine, designed and built by the Electro Dynamic Co., of Philadelphia, for this purpose.

In designing these machines particular attention was given to the demand that they be light in weight, as in many cases the machines are mounted on trucks, thus making them portable. This is easily done, as the machines are small and require no belt connections, and are easily connected to the source of supply by a flexible conductor. The design is such that but

one field and armature core is required—the two windings of the armature, motor and generator—being connected to commutators on opposite end of the armature. Regulation of the output can either be made by a rheostat connected in the motor armature circuit or in the generator circuit. Where the machine delivers heavy currents, it is more convenient to place the regulating rheostat in the motor armature circuit. The accompanying illustrations show two machines of this type. Fig 1 is a 2.5 kw machine, running at 110, 220 or 500 volts at the motor end and delivering 500 ampères at 5 volts. Fig. 2 is a 1 kw machine, running at 110, 220 or 500 volts at the motor end and delivering 200 ampères at 5 volts. Machines of this type are also made for an output of 100 and of 500 ampères.

The manufacturers, the Electro Dynamic Co., Philadelphia, Pa., will gladly furnish any information concerning their machines that may be desired.

## RESEARCH LABORATORY AT NIAGARA FALLS.

A company have recently been incorporated at Albany, N. Y., under the name of the Niagara Research Laboratories, their object being stated as follows: To maintain a research laboratory for scientific investigation at Niagara Falls; to do analytical and experimental work for the general public; to act as consulting engineers and experts in perfecting and improving existing processes; to rent space, power and the use of the laboratories for physical, chemical and electrochemical investigations; manufacture and sell chemicals and allied products, apparatus and supplies.

The engineers in charge of the laboratory are Messrs. F. M. Becker, L. E. Saunders and R. A. Witherspoon, all well known to the electrochemical fraternity on account of the active part they have taken in the development of processes now in successful operation at Niagara Falls. Among the directors are W. S. Gray and J. G. White, of New York City; W. B. Rankin, of Niagara Falls; N. M. Pierce, Binghamton, N. Y.; W. G. Case, H. J. Pierce, E. B. Stevens and Dr. Elmer Starr, of Buffalo.

## *Personal.*

The numerous friends of Dr. F. Haber in this country will be pleased to hear that, at the request of the German Imperial Commissionary for the St. Louis Exposition in 1904, Dr. Haber has worked out a general plan for the German exhibits of the chemical and apparatus industries. This plan has found the approval of the German Government, as well as of the most prominent representatives of these industries in Germany. It will be remembered that Dr. Haber, who is the professor of electrochemistry at the Institute of Technology at Karlsruge, paid last year an extensive visit to this country.

It is expected that a great number of American scientists and engineers will attend the International Congress for Applied Chemistry in Berlin. Among those who will sail on May 12th are Dr. W. R. Whitney, Schenectady, N. Y., and Mr. Edw. R. Taylor, Penn Yan, N. Y.

Dr. Rudolf Gahl, who was formerly an engineer of the well-known Hagen storage-battery concern, in Germany, has recently accepted a position with the Electric Storage Battery Co., Philadelphia, Pa.

Dr. Th. Zettel, who has been connected with various electrochemical enterprises in Europe, and has translated Moissan's works into German, is visiting this country.

## DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

*Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.*

*This digest of electrochemical United States patents priar to July, 1902, will be one by classes, setting out for comparison in each class those devices which have the same object, or those methods which seek the same results. In each class the patents will be arranged chronologically. The digest will be complete in the sense of covering every point which is touched upon in the original specification.*

690,141. December 31, 1901; Wilhelm Gintl, Aussegg, Austria-Hungary.

Rectangular bells are arranged transversely, in longitudinal series, in an open vat. The bells are of glass or earthenware, surrounded by a sheet-iron casing, serving as cathode. Each bell may have a separate chlorine outlet, or the chlorine may be led from bell to bell, and thence out. A rectangular carbon anode nearly fills each bell, and the brine is introduced above the anode through a horizontal pipe having a series of openings in its upper side. The brine flows down around the sides of the anode or through a series of openings in it, and the caustic solution is continuously drawn off from a point outside the bell. May electrolyze fluorides and carbonites.

690,305. December 31, 1901; Wilhelm Gintl, Aussegg, Austria-Hungary.

The apparatus shown in previous patent.

695,033. March 11, 1902; Edwin D. Chaplin, Winchester, and Henry G. Halloran, Boston, Mass., assignors to Henry Dakin, Boston, Mass.

Separates anode and cathode compartments by a double diaphragm of asbestos cloth, and feeds brine into the intermediate space. Cell consists of a lower circular pan of stoneware and a circular upper portion having an outer depending rim, between which and the pan rim is clamped the diaphragm. An annular partition within and concentric to the outer rim depends from the upper portion, and is secured to the diaphragm by a wooden ring and pins. A single horizontal sheet thus provides a double diaphragm, with space intermediate the electrode compartments. Anodes, an annular series of carbon bars in the outer compartment above the diaphragm. Cathode, a horizontal spiral coil of sheet copper, in the inner compartment, above the diaphragm. A rotatable overflow pipe, with a goose neck at the end, leads from the central cathode compartment, maintaining any desired level.

697,157. April 8, 1902; Frank McDonald, Rumford Falls, Me.

Tank divided transversely by an anode compartment, consisting of parallel, vertical, perforated iron plates, lined with layers of asbestos cloth and paper, which serve as diaphragms. Top of anode compartment closed by a flanged cover of glass, through which extend a plurality of anodes. Each anode consists of a bunch of platinum-foil ribbons, sealed into the lower end of a glass tube, with mercury contact and current wire. Brine is supplied to the anode compartment by a float-feed device. Caustic is delivered from the cathode compartments by rotatable overflow pipes leading from the bottom.

703,289. June 24, 1902; Hugh Kelsea Moore, Lynn, Mass., assignor to Moore Electrolytic Co., Portland, Me., and Boston, Mass., a corporation of Maine.

Cell consists of a vertical, rectangular, open frame of slate, the sides of which are closed by diaphragms of asbestos paper, clamped in place by cathodes, each consisting of a layer of wire cloth and a perforated iron plate. Anode, a series of vertical carbon plates, the lower ends of which rest in a groove in the bottom of the frame. Brine is continuously supplied by an adjustable float-feed device, and percolates through the diaphragms, and the sodium deposited on the cathodes is oxidized and washed down by the excess solution into a shallow pan, which receives the lower end of the cell. Each cathode is inclosed by a casing, which depends into the caustic solution collected in the pan and excludes air, thereby preventing oxidation of the cathode, evaporation of the liquid contained in the cathode, deposition of magnesium or calcium and carbonating of the caustic. The accumulating hydrogen forces its way out through the caustic in the pan. The sides of the cell converge toward the bottom, thereby progressively decreasing the resistance of the electrolyte from the top to the bottom of the cell to compensate for the increased flow toward the bottom, due to the pressure of the column.

*The part of the digest of United States patents relating to alkalies and chlorine is herewith concluded.*

# Electrochemical Industry

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## Electrochemical Industry

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**NOTICE.—After June 1, 1903, the offices of the ELECTROCHEMICAL INDUSTRY will be located at 114 Liberty street, N. Y.**

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## ANNOUNCEMENT.

On June 1st the offices of ELECTROCHEMICAL INDUSTRY will be transferred to New York City. There will be no change either in the business or the editorial staff. As the metropolis and center of the industrial activity of the United States, New York has become the seat of nearly all the leading technical journals of this country, as well as of most of the national engineering societies. A technical newspaper, which endeavors to be a newspaper in the best sense of the word, can only in the highest degree discharge its functions by keeping constantly in touch with the men alongside of the facts—those who make the history of the industries of this country. It is with regret that the members of the staff of ELECTROCHEMICAL INDUSTRY leave old, beautiful Philadelphia, but this regret is accompanied by the recognition of the fact, which became more evident from day to day, that at their new seat of activity they will have better opportunities than heretofore for manifesting their devotion to the cause in which this journal is enlisted.

In the nine months of its life, ELECTROCHEMICAL INDUSTRY has won many friends. While we have refrained so far from speaking for ourselves, and have preferred to let ELECTROCHEMICAL INDUSTRY stand on its own merits, we may here thank our friends for the support they have given us. ELECTROCHEMICAL INDUSTRY is read wherever there is chemical, metallurgical or electrical activity. Our friends are found in the laboratories and workshops of the manufacturing concerns, not only in this country, but all over the world. We doubt whether any technical journal has ever acquired in such a short time a subscription list so fully representative of an art and industry. To all our friends we send our greetings and renew the promises made when this journal was started; and we trust that in its new home ELECTROCHEMICAL INDUSTRY will be found even more ardent than heretofore in its zeal to be the worthy journalistic exponent of the young, splendid and swiftly advancing industry whose name it bears.

## ELECTROPLATING.

In this issue we publish two interesting articles on electroplating, especially nickelplating, which somewhat supplement each other, the one by Messrs. C. F. Burgess and Carl Hambuechen on the most suitable form of the anode, the other by Mr. D. H. Browne on the well-known phenomenon of curling up of electrolytically-deposited nickel sheets. At first sight electroplating appears to be the most simple problem of electrochemistry. We have an electrolyte, the cation of which is the metal to be deposited, and an anode of the same metal, so that the same quantity of metal which is deposited on the cathode goes into solution at the anode and the conditions should be unchanged. It will, however, be seen that under no circumstances is the matter so simple. Even if the process

goes on in the first moment in the way just described, the conditions are at once changed on account of concentration changes developing at the anode and cathode, the layer of electrolyte on the cathode surface becoming more dilute and the layer on the anode surface more concentrated. We have, therefore, in the second moment an electrochemical system different from the original one.

The principal problem in electroplating is, however, as Mr. Browne puts it, to maintain initially good conditions to the end. Any influence which tends to change the conditions must be counteracted. This is the reason why stirring the electrolyte or revolving the electrode is of such importance, because the concentration of the electrolyte is thus made uniform throughout the cell and new ions are supplied to the points where they are wanted and where their number has decreased, in the surface layer next the cathode. The account of the extended experiments of Mr. Browne concerning the best conditions for electrolytically depositing nickel sheets of almost any desired thickness will be read with great interest.

The phenomenon of curling up of electrolytically-deposited nickel sheets is undoubtedly due to a difference in surface tension on both sides of the sheet. The tendency to curl increases with the current density used, but the curling is always anodeward and around the longer axis of the rectangular cathode, irrespective of the way in which the cathode hung in the bath. This brings up the question whether the variation of the current density over the surface of the cathode has here not an important influence, analogous to that shown by Messrs. Burgess and Hambuechen to exist in the case of the anode.

Theoretically the quality of the deposit obtained should depend upon nothing but the conditions which exist in the surface layer of electrolyte next to the cathode. If the metal of the cathode alloys well with the metal to be deposited or is otherwise a suitable material for yielding a firmly adherent deposit, and if the layer of electrolyte next to the cathode contains a sufficient number of cations to be deposited with the current density employed, then the deposit should be good. Theoretically, therefore, the quality of the deposit does not depend on the anode, as there can be no action into the distance. But it can easily be seen that it would be absolutely wrong to believe that the form of the anode does not matter.

As was said before, the main problem in electroplating is to maintain initially good conditions. For this purpose it is necessary that the same amount of metal is dissolved at the anode as is deposited on the cathode. An easily soluble salt should therefore be employed, and the anode should be chosen of proper size and form. As Messrs. Burgess and Hambuechen point out, the lower the current density at the anode, the more nearly does the amount of metal corroded correspond to the electrochemical equivalent, and especially is this the case with nickel. A nickel anode should present as large an active surface to the electrolyte as possible.

It has long been found in practice that ordinary nickel sheets are not suitable as anodes in an electroplating bath, and that it is necessary to artificially increase the active surface of the anode. This is, for instance, done by the use of corrugated anodes. But it would be wrong to confuse active surface and real surface, as the term active surface takes the current into account which flows from each point of the anode into the electrolyte. Now, Messrs. Burgess and Hambuechen point out and prove experimentally that the active surface greatly depends on the shape of the anode. The diagrams in their article show this clearly. With a rectangular cross section, the distribution of current is much less uniform over the entire surface, than with an oval cross section; and this proves that while with a corrugated anode the actual surface is increased, the active anode surface is not increased in the same proportion, although sufficiently to give good results in practice.

Messrs. Burgess and Hambuechen point out the practical advantages of the use of oval anodes. While corrosion goes on, the electrode retains its original shape, until reduced to a very thin rod or strip; the amount of scrap from oval anodes is about 5 per cent., while with rectangular anodes there is a waste of about 15 per cent. While oval electrodes may require a greater amount of nickel to be suspended in the tank, the authors believe that this disadvantage is more than compensated by the saving in the less frequent removal of electrodes and the smaller amount of scrap.

## ANODIC FORMATION OF INSOLUBLE COMPOUNDS.

Among the Synopsis abstracts of this issue there is an abstract of an interesting paper of Isenburg on a special case of Luckow's method of forming insoluble compounds at the anode. The principle of this method may best be explained by a special example for which we may take the formation of white lead, which is the case dealt with by Isenburg. Of course, a lead anode is to be used and the electrolyte must contain $CO_3$ ions in order to form lead carbonate, but the main principle of Luckow's method is that the electrolyte should contain another anion besides $CO_3$, so that he has a mixture of two electrolytes and a double anodic reaction, the one anion forming the insoluble compound wanted at the anode and the other anion forming a soluble salt. It is an important feature that the second salt formed at the anode should be soluble.

For the formation of white lead a mixture of potassium chlorate and potassium carbonate is used as electrolyte with a lead anode. For the formation of lead chromate a mixture of potassium chromate and potassium chlorate is used with a lead anode. It is an established fact that the formation of the insoluble compounds wanted goes on easily, if the second electrolyte (which when acting on the anode gives the soluble salt) is present in a relatively large proportion. This fact seems at first sight somewhat mysterious and requires an explanation. Why is the second electrolyte, which gives the soluble salt, necessary for the easy formation of the insoluble compound, and why must its concentration be relatively great, compared with that of the first electrolyte, which gives the insoluble compound wanted?

An explanation of these facts was given by LeBlanc and

Bindschedler in the case of lead chromate, and the same explanation has been found by Isenburg to be valid for white lead. It is that the addition of the second electrolyte has the result that the formation of the insoluble salt occurs at some distance from the anode and not directly on the surface. If it would occur directly on the surface of the anode, a layer would be formed which sticks to the plate and another chemical reaction would begin which is not wanted; for instance, if the lead chromate is formed directly on the surface, it becomes now the active anode and the new electrochemical action is the formation of lead peroxide which is not wanted.

To make this explanation clearer, we may take the case of the production of lead chromate by using a mixture of potassium chromate and potassium chlorate with a lead anode. In the first moment of electrolysis both lead chromate and lead chlorate are formed, and the layer of electrolyte next to the anode becomes poor in chromate anions which were present in a relatively small quantity from the beginning. The very thin coating of lead chromate formed on the anode surface in the first moment is assumed to be washed off, so that we then have a lead anode and next to it a layer of electrolyte containing mainly lead chlorate and potassium chlorate, but no chromate; this layer is in contact with the original electrolyte. It is thus evident that the formation of lead chromate cannot any longer occur directly at the anode surface, because there is no chromate in contact with it. The formation of lead chromate will take place at the boundary surface where the electrolyte layer containing no chromate anions, but lead cations (in the form of lead chlorate) is in contact with the original electrolyte. The insoluble salt which is formed there cannot stick to the anode, but falls to the bottom of the cell, and that is what is wanted. The lead anode surface remains bright and remains lead, and the reaction can go on without disturbance. It seems that if this is the complete and correct explanation, the arrangement of the process could be improved.

It is evident that stirring of the electrolyte should here have a bad effect because it destroys the layer of electrolyte next to the anode and brings chromate again in contact with the anode. On the other hand, stirring would have one good effect, as it would help to wash off from the anode surface the thin layer of lead chromate which must be formed in the first moment. There should therefore be noticed bad and good effects when the electrolyte is circulated. Isenburg made some experiments in this direction, but could not get conclusive results; the matter becomes evidently greatly complicated. It is, however, evident that the subject is of great interest and importance, and if the above explanation should prove to be correct, the trick on which Luckow's method is based could find many useful applications.

## ELECTROLYTIC PRODUCTION OF BLEACH LIQUORS.

In our former issues the Digest of electrochemical patents prior to July 1, 1902, has dealt with the electrolysis of chloride solutions for the purpose of obtaining therefrom chlorine, and the hydrate of a metal, generally caustic soda. The problem, therefore, has been how to separate, and how to maintain separated, the anode and cathode products. This has been accomplished in many ways, by absorbing the cation in mercury; by causing the anion to form an insoluble compound with the metal of the anode; by diaphragms interposed between the electrodes; and by special cell constructions in which dependence is placed upon the movement of the electrolyte or upon the difference between the specific gravities of the products. These cells are essentially complex.

The Digest now turns to cells for the production of bleach liquors, and there is found a radical departure in principle and structure; for in general the bleach liquor is a hypochlorite, and is produced by the reaction of the anode and cathode products, as sodium hypochlorite by the action of chlorine upon caustic soda. This reaction is generally permitted to occur within the electrolytic cell, and is facilitated by the juxtaposition of the electrodes and the relatively rapid movement of the electrolyte. The necessities of proximity and parallelism of the electrodes, less resistance, and simple electrical connections indicate the peculiar adaptability for this purpose of the series system of electrode connections.

## ELECTROLYTIC AND METALLIC CONDUCTION.

At the recent New York meeting of the American Electrochemical Society the proper definition of metallic and electrolytic conduction was the subject of quite an extended discussion. In general, there cannot be any doubt how to distinguish between metallic and electrolytic condition. If a current flows through a wholly metallic circuit, there is no chemical change; if it flows through a circuit containing an electrolyte with electrodes, there is a distinct chemical change at the electrodes, consisting of oxidation and reduction. But if we have an electric circuit wholly made up of electrolytes without any metals, then if a current flows through it, there is no possibility of oxidation and reduction; there is no possibility of the ions giving off their charges. Nevertheless, there is no reason whatever to assume that in this case the mechanism of the conduction in the interior of the electrolyte is in any way different from the mechanism of conduction when electrodes are used. It was correctly said by one of the speakers in the discussion of Mr. Marvin's paper that the movement of the ions in the interior of the electrolyte is governed alone by the force acting on them at that place (*i. e.*, by the electric drop of potential at that point and by the osmotic force) and by nothing else; the ions "do not know" whether there are electrodes in the circuit at some distance or not; the movement of the ions at a special point in the electrolyte depends on the electric field at that point and it does not matter whether this electric field has been produced with or without electrodes at some distance.

The experiments described in Mr Marvin's paper, which was abstracted at some length in our last issue, are quite interesting; they prove the existence of an alternating current in a wholly electrolytic circuit. This might perhaps be proved even in an easier way by setting up eddy currents in an electrolyte by means of an external circuit and proving the existence of these eddy currents by measurements of the power consumed when the eddy currents are produced and when the electrolyte is taken away. This might give a method of measuring the conductivity of a solution without the use of electrodes.

## UNION ENGINEERING BUILDING.

A meetmg of the chosen representatives of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Mining Engineers, the American Institute of Electrical Engineers, and the Engineer's Club, was held in New York City, May 15th, to discuss the proposed gift of $1,000,000, by Mr. Andrew Carnegie, for a union engineering building.

There were present Messrs. Dodge, Dwight, Fletcher, Hunt, Hutton, Kafer, Kirchhoff, Ledoux, Martin, Noble, Pegram, Redding, Scott, Wilgus. Mr. Charles F. Scott was chairman, and Prof. F. R. Hutton, secretary of the meeting. After a very harmonious and extended discussion the following resolution was passed unanimously:

*Resolved*, That this Joint Conference Committee recommend to the respective governing bodies represented at this conference, that the following resolutions be brought before the several organizations to be acted on:

*Resolved*, That (insert name of organization) unite with (insert the names of the other four organizations), or any of them, for the purpose of accepting the sum of $1,000,000 as a gift from Mr. Andrew Carnegie, for the purpose of erecting suitable buildings for occupancy by various societies of engineers and the Engineers' Club, on the sites secured for that purpose on the north side of Thirty-ninth street, and south side of Fortieth street, west of Fifth avenue, in the city of New York, in the State of New York; and

*Resolved, further*, That (insert name of organization) has a very high appreciation of this generous gift of Mr. Andrew Carnegie, and this additional evidence of his recognition of the engineering profession and his deep interest in the welfare of the national societies of engineers and the Engineers' Club; and

*Resolved, further*, That a site on the north side of Thirty-ninth street shall be purchased and held by trustees, or otherwise, as shall be determined by the Joint Committee hereinafter mentioned for the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the American Institute of Mining Engineers, or by such of them as shall vote in favor of coming into this enterprise; and

*Resolved, further*, That a joint committee shall be created to be composed of three members of each organization that shall unite in accepting said gift of $1,000,000 from Mr. Andrew Carnegie; and that the governing body of (insert name of organization) shall elect three members of this organization to represent it on and be members of such joint committee; and that the governing body of (insert name of organization) shall have the right and power to remove any member of such joint committee who shall be elected by it, and to elect any member of this organization to fill any vacancy that shall occur in such joint committee by reason of the death, resignation, refusal to act or removal of any member who shall have been elected by the governing body of this organization as a member of such joint committee; and

*Resolved, further*, That the character and internal arrangement of the building to be erected on the site on Thirty-ninth street, shall be determined upon by the affirmative vote of at least two-thirds of all of such of the members of said joint committee as shall represent all of the organizations, other than the Engineers' Club on such joint committee, and that the character of the internal arrangement of the club building to be erected on the site on Fortieth street, shall be determined upon by the affirmative vote of all of the three members of such joint committee who shall represent the Engineers' Club on such joint committee; and

*Resolved, further*, That said joint committee shall, by the affirmative vote of at least two-thirds of all the members thereof, select and employ an architect to prepare the plans and specifications for the building to be erected on the site on Thirty-ninth street, and for the club building to be erected on the site on Fortieth street; and shall also obtain proposals for the erection of both of such buildings; and shall have power to make and enter into such contract or contracts as shall be approved and authorized by the affirmative vote of at least two-thirds of all the members of said joint committee, for the erection of both of such buildings; and shall have charge of the erection of both of such buildings; and

*Resolved, further*, That said joint committee shall continue in existence until all of the purposes set forth in these resolutions shall have been fully accomplished.

The secretary was authorized to transmit a copy of the above resolutions to each chairman of the constituent committee present, with a request that the latter should transmit the action of the meeting to the governing body of each respective society.

## NIAGARA FALLS MEETING OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

The annual convention of the American Institute of Electrical Engineers will be held at Niagara Falls, N. Y., June 29th to July 3d. The mornings from 9.30 to 1.30 will be devoted to the presentation of papers, while the afternoons and evenings will be devoted to the inspection of places of technical and historical-interest. Excursions to various localities in Niagara Falls and Buffalo will be arranged for the members of the Institute and their guests.

Papers for the convention will be presented in the following order: On Monday morning, Mr. C. F. Scott will deliver his presidential address, to be followed by papers and discussions relating to the scope and development of the Institute, with particular reference to the organization of local branches. The topics of the papers for Tuesday morning will be "Electric Traction," for Wednesday, "Long-Distance Power Transmission," and on Thursday, papers on miscellaneous other subjects will be read. Among the papers announced there are the following: "The Storage Battery in Sub-Stations," by W. E. Goldsborough and P. E. Fansler; "The International Electrical Congress of 1904," by Elihu Thompson; "Symbols and Nomenclature," by Carl Hering; "The Magnetic Units," by Dr. A. E. Kennelly; "The Legalized Standard of Electromotive Force," by Prof. H. S. Carhart; "Institute Branch Meetings, their Organization, Development and Influence," by Calvin W. Rice.

Mr. H. W. Buck, of the Niagara Falls Power Co., has been appointed Chairman of the Niagara Falls Local Committee, and will have general charge of all local details. The transportation arrangements are in the hands of a committee, with Mr. E. H. Mullin, 44 Broad street, New York, as chairman.

## FALL MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

As it has been found impracticable to hold the fall meeting of the American Electrochemical Society at Boston, as originally planned, Niagara Falls will probably be the place selected for the meeting. The intention is to hold the spring meeting next year in Washington, and the fall meeting at St. Louis. The Mayor of St. Louis, and the Business Men's League, of the same city, have already sent official invitations to the Society.

American Institute of Mining Engineers.—We have received from the secretary of the Institute advance copies of the following papers: "Some Practical Suggestions Concerning the Genesis of Ore Deposits," Boehmer; "Operations of the Hudson River Water Power Co.," Parsons; "Zinc and Lead Deposits of Northern Arkansas," Adams; "Note on the Influence of the Rate of Cooling on the Structure of Steel," Sauveur and Boynton; "The Geographical and Geological Distribution of the Mineral Deposits of Mexico," Aguilera; "Ore Deposits Near Igneous Contacts," Weed.

## THE COMPOSITION OF ELECTROPLATING SOLUTION.

Some interesting notes on this subject are given in a paper presented by DR. N. S. KEITH at the New York meeting of the American Electrochemical Society. In the following we give an abstract of this paper:

In an electroplating bath with soluble anodes, the metal dissolved from the anode should be substantially equivalent in quantity to the metal deposited on the cathode, the composition of the bath remaining practically unchanged. This ideal condition is never fully attained in practice.

In electroplating and electrotyping the anodes should be of the pure metals, otherwise the impurities will either enter the electrolyte, thus changing its constitution, or they may, if insoluble, form crusts on the anode, consisting of insoluble and non-conductive salts.

An example of the first case is that from a copper anode containing iron, in a copper sulphate solution, iron will be dissolved, more copper will be deposited on the cathode than is dissolved from the anode. In this way the constitution of the electrolyte is progressively changed, until finally it becomes unfit for use.

An example of the second case is that if there be lead in the anode, a lead sulphate is formed thereon. If in considerable quantity, there may be a partially-insulating coating on the anode, which obstinately adheres thereto or falls off from time to time. But in this case, as in the former, the integrity of the electrolyte is gradually destroyed.

In cases where there are metals which are electronegative to the copper of the anode, there is a local electrolytic action by which copper is dissolved beyond the equivalent due to the operative current and to the deposit on the cathode, so that the electrolyte is unduly enriched.

In the operation of electrolytically refining copper all of these conditions exist; therefore the electrolyte has to be more or less frequently regenerated by change in quantity of one or more of its constituents, or discarded altogether for new.

The ideal electrolyte, wherein metal is to be transferred from the anode to the cathode, is a solution of that metal which has no corroding effect on either the anode or cathode when no current is flowing through the cell. Such a solution may possibly be made, but is maintained with difficulty during operation. For instance, a neutral cupric sulphate solution has, unaided, no appreciable effect on pure copper, but under action of current, except of quite low density, coatings of a basic sulphate form on the anode, and for a time more copper is deposited than is dissolved. Then, in order to pass current, an increase of voltage is necessary. Then follows a deposition of hydrogen on the cathode, with an equivalent oxidation of the anode without corresponding solvent action.

If the cupric sulphate solution be acidified by addition of $H_2SO_4$, then the current density may be increased, because there is more of the anion quantity available. But it may be necessary to increase the quantity of Cu, so that the cation quantity may be equal to the extent of fully satisfying the requirements of the density of current. Otherwise H will be deposited with the Cu, and the electrolyte depleted of its essential constituent, Cu.

Agitation of electrolytes is necessary in operating with high densities of current, in order to have abundant supplies of the suitable ions at their proper places at the surface of the electrodes, heat assisting both agitation and solvent action.

The foregoing considerations justify the conclusion that the use of strong solutions as electrolytes, with abundant solvent of the salt formed at the anode and rapid agitation or circulation, will allow of great densities of current, insuring rapid deposits of metal. These interdependent conditions, properly balanced and operated, will insure also the desired quality of deposit within the characteristic possibilities of each metal as to its crystallinity or its amorphous condition.

The author discusses gold plating, with the use of a solution of gold cyanide in a solution of potassic cyanide. This is generally worked while hot. Now, gold is not, contrary to general acceptation, dissolved by a solution of potassic cyanide. But auric cyanide is. To dissolve gold in a solution of potassic cyanide without electric current, it is necessary to furnish some element to displace the CN of the KCN, so that it may be free to unite with Au to form AuCN. This element, in practice of cyaniding gold ores, is oxygen. If only half of the necessary oxygen be supplied, there is a further change, involving the decomposition of some of the water of the solution. It will readily be seen how essential is the presence of oxygen. By exposure to air, such a solution absorbs oxygen, and thus becomes a ready solvent of gold from both electrodes, thus changing the solution. Under current, CN is the anion, and acts directly to unite with the gold of the anode. But such a solution is worked with a high voltage and high density of current, for practical results, with a strong evolution of both oxygen and hydrogen.

To preserve the integrity of the electrolyte, in so far as its contents of gold is concerned, the electroplater varies the area of the anode, making it more or less to increase or decrease the contents of gold so dissolved; generally by guess, under the "rule-of thumb," guided somewhat by experience. The cathode is kept in constant, rapid motion to remove the bubbles of hydrogen, so that the gold cation may have access to the cathode surface. Such coatings of gold have quite imperfect adhesion, especially on metals which are electropositive to gold in cyanide solutions. To obviate this defect as much as possible, the operator makes the necessary electrical connections to the electrodes before immersing the cathode in the bath.

Gold is seldom deposited to any thickness exceeding one-ten thousandth of an inch, and oftener not more than one hundred thousandth of an inch. Such a deposit cannot be considered a protective coating for a great length of time, even under ordinary atmospheric conditions, and not at all under the action of corrosives of the metallic body which it overlies.

No matter how well the article may have been cleaned*, or how well it may have alloyed with the gold†, or been bombarded‡, the deposit is porous and the metal underneath is still subject, though in a lessened degree, to the action of corrosive gases and liquids. The oxides, chlorides, nitrates and sulphides thus formed at the exposed places on the baser metal require more room, so they exude, creep under the coating and spread themselves over it, so as to, in time, completely hide the gilding. Thus it may be mistakenly thought to have found its way, as an alloy, into the substance of the baser metal. Etching will dissolve the oxides, etc., and again expose the gold on the surface of the article§.

No matter how nearly perfect an electroplating solution may be, nor how skillfully operated, the deposit increases in roughness with thickness. In electrosilvering the operator from time to time removes the cathode, and smooths the deposit by "scratch brushing" with a brush made of metallic wires. He is thus enabled to secure any desirable thickness of deposit of silver and a thoroughly protective coating, because he closes the pores of the deposit by the burnishing action of the brush.

These solutions used to the transfer of metals, which contain no free acid of the kind which is a constituent of the salt of the metal transferred, are the most permanent and least liable to decomposition in operation, provided that salt is readily soluble in the liquid and that liquid has no action, by itself, on the metal. As an example, the author remarks that some years ago he began a series of experiments having for their object the refining of lead base bullion, and separating its contents of gold and silver by electrolysis. His first work was done in solutions of lead acetate and of lead nitrate (U. S. patent No. 200,056, 1878). But the integrity of such solutions could not be maintained. They were gradually decomposed

* Burgess & Hambuechen in *Electrochemical Industry* Vol. I p. 204.
† Kahlenberg in *Electrochemical Industry* Vol. I p. 201.
‡ Johnson in *Electrochemical Industry*, Vol. I p. 312.
§ Kahlenberg in *Electrochemical Industry* Vol. I, p. 201

with the formation of basic salts, insoluble on both anode and cathode, and some soluble in the liquid. The deposits then became unsatisfactory. Such solutions in the cases of all metals are impracticable for continuous work on a large scale. Like effects are the result in working cyanide solutions if the cyanogen constituent is not, from time to time, renewed. The author overcame this defect in the process of refining lead by using as a vehicle for the transfer lead sulphate, and as a roadway a solution of sodic acetate, in which lead sulphate is readily soluble (U. S. patent No. 215,463, 1879). The anion $SO_4$ readily attacked the lead anode, and the solution of sodium acetate at once dissolved the lead sulphate. In this solution, without access of oxygen, lead remains bright and unattacked. Under the action of current of reasonable density, its integrity is preserved indefinitely. The same amount of lead is deposited as is dissolved, and no gases are evolved. The acetate of soda remains unchanged.

The general tendency in electroplating solutions in operation is to form oxy-salts at the anode. Or, in other words, oxygen becomes an active anion to act jointly with the acid anion of the salt, which is the true vehicle by which the transfer is made. This is undesirable, and if avoided, either by suitably composing the solution or by properly operating it, the best results will be attained.

## MODERN ELECTROLYTIC COPPER REFINING.

In his paper on this subject, read at the New York meeting of the American Electrochemical Society, Mr. Titus Ulke calls attention to the great difficulty of obtaining absolutely reliable data regarding many electrolytic refining processes and plants, on account of the peculiar secretive policy adopted by most electrolytic refining companies. The author holds, with Dr. Douglas, that the managements of copper-refining companies might profitably adopt the methods of the American iron and steel makers and allow engineers free access to all parts of their plants, and thereby encourage a free exchange of ideas and the obtaining of mutual benefits, which are generally of far greater importance than any temporary advantage gained by secretive methods.

There is very little to choose between one brand of electrolytic copper and another. All are good, and all have been brought to that high standard by expert labor and expert experience of instruments in expert establishments; whereas had there been co-operation on points of purely technical manipulation, the same results would have been obtained at infinitely less expense. The author has inspected most of the refineries in this country and abroad, and claims that all the so-called mysteries of electrolytic copper refining may be resolved into certain, now more or less well known, simple rules of practice.

The material at present subjected to profitable electrolytic treatment in the world's copper refineries is invariably a precious metal-bearing crude copper, cast into anodes assaying at least 96 per cent. Cu, with only one or two unimportant exceptions, and generally refined by fire methods up to 98 or 99 per cent.

The initial cathode sheets, or starting plates, of plants arranged according to the multiple system, are invariably thin sheets of electrolytic copper, obtained by deposition upon and stripping from greased, oiled or varnished plates of either copper or lead. The commercial cathodes are allowed to reach a thickness which is generally fixed at 0.5 to 0.75 inch in the multiple process, and 0.25 to 0.45 inch in series arrangements.

Solutions containing not less than 12 per cent. and not over 20 per cent bluestone, and from 4 to 10 per cent. free sulphuric acid, are employed almost universally. It is very important that the constantly-decreasing acidity and the constantly-increasing copper contents of the electrolyte be maintained within these limits. A small quantity of common salt or magnesium chloride, or, better, hydrochloric acid (say, 300 cc to a tankful of solution), is always added upon commencing operations, in order to hinder any possible dissolving of silver and to prevent "sprouting" or brittleness of the cathodes or starting sheets. Ammonium sulphate is sometimes added to the solution when considerable arsenic is present. Heating the electrolyte up to between 40° and 50° C. is advantageous, because it decreases the electrical resistance of the solution and increases the tensile strength of the copper.

Current densities ranging from 4 to 45 ampères per square foot of cathode surface are employed, the ampèrage used depending chiefly on the cheapness of power, the grade of the anode in silver and impurities, and the purity of the electrolytic solution.

The voltages measure from 0.1 to 0.3 volt between each row of plates in series tanks, and generally from 0.2 to 0.4 volt between the tanks when the plates are arranged according to the multiple system.

The following products of refining are marketed: Commercial cathodes, which are occasionally shipped to the consumer as such, but are generally cast into wire bars, ingots, cakes or slabs of standard dimensions and weight. They usually assay from 99.86 to 99.94 per cent. Cu. The yield in commercial cathodes is 97 to 99 per cent. of the weight of anodes treated, barring the anode scrap, which ranges from 7 to 15 per cent. of the anode weight in multiple plants to as much as 30 per cent. (probably) in a certain refinery with electrodes arranged in series circuit. About 1 to 3 per cent. of the copper treated is generally recovered as blue vitriol. Besides electrolytic copper and bluestone, many refineries produce fine silver and fine gold, togther with some base bullion from the anode slimes; and occasionally nickel salts, arsenious acid and tellurium, which products are recovered in purifying or working up the foul electrolytes.

A comparison of the methods and appliances used to-day with those employed only ten years ago shows that many important improvements have been made, nearly all of which are of American origin, and resulted from the necessity of handling large outputs. The chief improvements, in the author's opinion, are the substitution of casting machines for hand ladling; the employment of mechanical conveyors and of pneumatic tongs or hooks for charging pigs into the anode furnaces; charging machines designed for the same purpose; improved anode molds and shape of anodes; the introduction of electrode-handling cranes for charging the entire tankload of plates at one operation; greater facilities for handling material in the shape of locomotives, trucks and tracks; improved form and construction of solution pumps; improved disposition and operation of tanks, so as to increase their capacity with the same floor space; improved design and support of tanks, so as to increase their life and at the same time permit of their ready inspection for leaks; arrangement of plant with head room below the tanks, so as to allow of a ready removal of the silver slimes from the tanks and to the silver refinery; improved circulation devices, applicable in special cases; standardization of the conditions in refining, due to a better knowledge of the chemical and physical conditions involved; increase of current densities; better checking of the chemical and mechanical properties of the electrolytic copper; simplification of the testing methods in the chemical and physical laboratories, and a general increased efficiency of plant and reduction of operating costs.

The author then gives statistical data on copper refineries from his "Copper Refining," which is to be issued shortly. Most of his statistical figures have already been noticed in Electrochemical Industry.

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The United States now produces electrolytic copper at the enormous rate of 278,800 tons per year, which, at $260 per ton, is valued at over $72,000,000.

## ANODES FOR ELECTROPLATING.

By Prof. C. F. Burgess and Carl Hambuechen.

An ideal electroplating process employs a combination of electrodes and electrolyte, such as will enable a firm adherent coating to be deposited upon the cathode without the electrolyte undergoing a change in composition. This requires that the metal shall be deposited in electrochemical equivalent quantities, and that the same amount shall go into solution at the anode. In most of the industrial electroplating operations, this requirement is difficult to fulfill, and the departure from ideal conditions necessitates employment of skill and constant attention of the operator to ensure uniformity of product. One of the chief sources of difficulty is at the positive electrode, and it is becoming appreciated by platers that attention given to the anode aids in obtaining satisfactory results at the cathode. The shape, structure, physical properties and the chemical composition of the anode are all factors which may largely influence the results.

If, as is frequently the case, the metal of the anode does not go into solution in proportion to the electrochemical equivalent, the solution becomes deficient in metal and requires the addition of certain chemicals to restore it to its original and working condition. It is the purpose to point out here some of the factors which influence the corrosion at the anode and to give the results of some measurements which have been made upon nickel anodes in a nickel-ammonium sulphate plating solution.

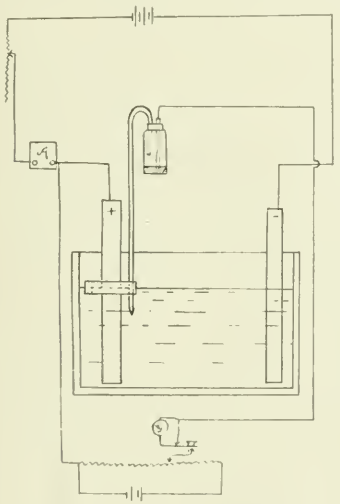

Fig. 1.—Method of Measurement.

It may be stated as a general principle that the lower the current density at the anodes, the more nearly does the amount of metal corroded correspond with the electrochemical equivalent, and especially is this the case with nickel. With the commercial forms of this metal, the current density must be kept below 5 ampères per square foot in order that a high current efficiency of corrosion may be attained. This, in turn, requires that the anode should present as large an active surface to the electrolyte as possible. It has been found that flat plates of nickel arranged along the sides of a plating tank do not present sufficient active surface to enable a suitably low anode current density to be used, and at the same time to deposit nickel upon the cathode as rapidly as may be desired. To overcome this defect, various improvements have been introduced to increase the amount of active anode surface. Among these improvements are corrugated anodes and the round or oval anode.

It is held by some that a porous metal casting having a coarse crystalline structure will corrode more rapidly than will a dense metal anode, and while this may be the case, there is introduced the disadvantage that the corrosion proceeding between the particles of the metal may cause pieces of some considerable size to become detached from the anode without being corroded, thus causing a considerable waste of nickel. A firm, dense casting gives a more uniform and even corrosion, and is, therefore, preferable to the porous castings.

The term "active anode surface" does not mean merely the area of surface which is exposed to the electrolyte, but rather the area exposed to the electrolyte from which current readily flows. The shape of the anode has much to do with the active anode surface as will be shown in the following diagrams.

Measurements were made upon nickel anodes suspended in nickel plating tank to determine the relative amounts of current flowing from each portion of the anode surface, anodes of two different types being used. One of them was the ordinary flat electrode, having the dimensions 6 x 9 inches, by 1/2 inch thick, and the other electrode had an oval cross section 2 1/2 inches long and 1 1/4 inches thick. While the measurements were being made, the anode was placed 1 inch from the side of the tank opposite a cathode, the distance between the anode and the cathode being 6 inches.

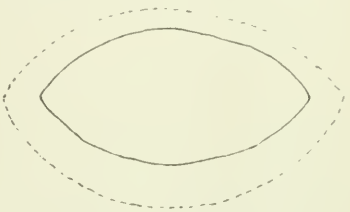

Fig. 2.—Diagram Showing the Variation of Current Density over the Surface of the Anode.

The method employed in making the measurements is illustrated in Fig. 1. The anode was fitted with a block of wood dipping just below the surface of the electrolyte. Through this block, holes were drilled at uniform intervals around the anode and 1/2 inch away from it. Through these holes the liquid terminal of a "calomel normal electrode" was introduced, and by measurement of potential between the mercury terminal and the anode terminal the fall of potential caused by the current flowing through the electrolyte was derived. The differences of potential were measured by the potentiometer method. The current flowing from the anode was adjusted so that a current density of about 5 ampères per square foot of exposed surface was obtained.

Fig. 3.—Diagram Showing the Variation of Current Density on the Anode Surface.

By determining the difference of potential between the anode and the normal electrode and deducting the contact potential of the electrolyte and electrode, the fall of potential through the electrolyte was obtained, and the current flowing was, therefore, proportional to such values. In this way the relative amount of current flowing from each portion of the electrode surface was obtained. The results are plotted in Figs. 2 and 3, the amount of current being proportional to the distance from the electrode surface to the dotted curve. With the rectangular cross section, it is seen that the distribution of current is much less uniform over the entire surface than where the anode of oval cross section is used. In the former, the part

of the electrode nearest the side of the tank undergoes very little corrosion and, consequently, that portion of the surface can hardly be considered as "active electrode surface." To make the curves as nearly comparable as possible, the cathode surface was in each case made about twice as large as the anode surface.

The shaded portion of Figs. 2 and 3, indicating the distribution of current, show, also, the manner in which corrosion takes place and the manner in which the electrode will be worn away. With oval electrode, the corrosion will take place in such a manner that the electrode retains its original shape, although, of course, decreasing in size, the corrosion continuing until the electrode is reduced to a very thin rod or strip. In addition to having a larger ratio of active to total anode surface with the oval than with the rectangular electrodes there seems to be the further advantage that the corrosion may proceed in the former until a larger percentage of the material has been used up before it becomes necessary to replace it with a new anode.

From the results of measurements made in an electroplating plant where both these forms of anodes have been in use, the following results were noted: An oval anode, the original weight of which was 11 pounds, had corroded until 1½ pounds remained, and the anode still retained its original shape and was capable of furnishing more metal to the solution. The necessary waste from this electrode, due to the method of suspension, was about ½ pound, so that the amount of scrap from such anodes may be figured at about 5 per cent. With rectangular anodes the original weight of which was 16 pounds, there was a waste of about 2½ pounds after the anode had become so far corroded that it had to be removed from the tank. This represents a waste of about 15 per cent. Inasmuch as the original anode material costs about 50 cents per pound, and the scrap nickel can be disposed of at about one-half that value, the amount of scrap represents a loss to the plater of about 25 cents per pound and is an item well worth attention.

With the anodes tested, the oval ones had a surface of about 6 square inches per pound of material, while the rectangular ones had a surface of about 14 square inches per pound. Inasmuch, however, as in the latter case, the surface exposed is not all active surface, while in the former case the proportion of active surface is much greater, these figures do not represent the relative amount of active area per pound. The desideratum of the electroplater is not to obtain a large active surface per pound of metal, but rather, obtain as much active surface per foot length of tank as possible. While oval electrodes may require a greater amount of nickel to be suspended in the tank, the disadvantage is only in the increased interest on the investment, and this item is more than compensated by the saving in the less frequent removal of electrodes and the smaller amount of scrap. A further advantage in the oval electrodes is the fact that a more dense casting may be obtained than where the electrodes are made flat and thin.

The corrugated electrodes present an advantage over the flat ones in exposing a greater amount of active electrode surface, but the active electrode surface is not increased in direct proportion to the actual electrode surface exposed to the electrolyte. This is due to the fact that the current does not leave the low parts of the corrugations as readily as it does the elevated points, due to the greater distance from the cathode and the less free circulation of the solution around the lower parts.

From the measurements and observations above described it appears desirable to subdivide the anode metal into rods or strips of such form that corrosion can proceed on all sides. It should be noted, however, that even with such subdivision the corrosion will not take place from the side of the anode away from the cathode unless the anode rods are placed a sufficient distance apart to allow free circulation of solution and flow of electric current through it.

## NICKEL CATHODES.

By David H. Browne.

The simplicity and convenience of preparing a copper cathode by the electrodeposition of the metal upon a sheet of lead, from which the coating is stripped when it has attained the desired thickness, is so obvious that much time and labor have been spent in attempts to prepare a similarly soft and flexible cathode sheet for use in nickel refining.

While such attempts are not of commercial importance, since a rolled cathode of nickel is much preferable to the deposited article, yet these researches are useful from the side lights which they throw on the character and properties of electrolytic nickel.

The bugbear encountered by all who attempt to produce sheets of nickel thicker than that used by nickel platers has been the tendency of nickel to crack and curl off in rolls, like wood shavings. This very analogy of the wood shaving helps us to understand the reason of the peeling of nickel. The reasons which I advance may or may not be borne out by theory, but they are readily proved by practice. The wood shaving curls into a helix because it is compressed on one side or expanded on the other. A similar difference in surface tension causes the curling of nickel deposits.

Suppose that the cathode be 10 centimeters square, and the distance between anode and cathode is also 10 centimeters. A liter of solution lies between the electrodes, and in this, in the common nickel ammonium sulphate bath, there are about 13 grams nickel. Now, suppose that the cathode be laid flat and this solution poured upon it till it commences to run off. The probable thickness of this wetting film is, say, for example, 1 millimeter. This figure is used only for argument's sake, but it gives us, as probably under the molecular attraction of the cathode at any one time, about a tenth of a gram of nickel. How much of this nickel is in the form of ions, free to deposit upon the cathode, is an unknown factor. Certainly, much less than a tenth of a gram.

Imagine now that all the free ions of nickel in contact be plated upon the cathode, and the solution be at rest. The film of solution in cathode contact rises, and in part diffuses back into the solution behind it; that is, toward the anode. If we imagine the current divided into impulses, we must see that the second impact of current has a lesser number of ions to act upon, and these, when deposited, are scattered and not contiguous. The next deposit comes down in still more scattered spots, and, as each particle of nickel attracts its neighbor, there arises a surface tension which finally exceeds the tensile strength of the metallic film and the air pressure which holds the film on the cathode. At this point the deposit cracks and curls anodeward.

On examining the fracture of a nickel cathode, which has been plated to a thickness of about an inch, it is seen to consist of a dense forest of small hairs, like the pile of velvet. Each hair is of the same thickness throughout, and each in contact with its neighbor. A poor cathode shows the hairs ending in a loose, irregular, mossy deposit, readily scraped off. The solid deposit is solid because there was brought into cathode contact sufficient ions to replace those thrown out by the current, so that at no time was the deposit impoverished and the growth of the fibers stunted. Just as a sheaf of wheat is smaller at the top than at the bottom, and just as velvet tends to curl toward the pile, so does the poor nickel deposit tend to curl toward the anode.

It is evident, then, that any condition which aids the replacement of the ions helps the deposit to remain flat. Circulation is, in this respect, most efficient. With a difficultly soluble salt no replacement, however fast, is certain to prevent local irregularities. Hence the use of more soluble salts, as nickel chloride, is of great benefit. Heat also, by giving mobility to the liquid and by causing eddies therein, is a useful ally. More than all is the employment of a steady density, since it is self-evident that a deposit hurled at the cathode with a cur-

rent density of 200 or 300 amperes per square meter must be different in its physical structure from that allowed to fall out of solution at a density of 50 or 75 amperes.

There is no secret about the production of solid nickel deposits of almost any desired thickness. The entire art consists in maintaining initially good conditions to the end.

The ordinary nickel plater hangs an object on a cathode bar, turns on a current, which is never measured; pulls the cathode out to see how it looks; puts it back and takes off some other article which is sufficiently plated. Meanwhile the solution is practically at rest. It is foul with all kinds of floating oxides; it has never been analyzed, nor tested, nor filtered. The cathode deposit has absolutely no chance to attain a respectable thickness, and if it were not for the great hardness of electrolytic nickel, which enables an exceedingly thin deposit to withstand rough usage, nickel plating would rapidly become a lost art.

Applying this rule to the production of thin sheets of nickel, the deposition from sulphate solutions offers no difficulty. Given a highly-graphited copper or tinned-iron cathode, a solution or neutral nickel sulphate or nickel ammonium sulphate, kept about 50° C., a pure nickel anode and an efficient system of circulation—with these conditions a deposit started at any density, from 50 to 300 ampères per square meter, can be carried through at the initial density, and will produce a smooth, slightly-mammelary sheet, which, on releasing one corner with a knife blade, will strip spontaneously and lie flat. Such a deposit is, however, glass hard and very springy, and, unless annealed, cannot be bent over a hanger.

Before it was discovered that a rolled nickel cathode was in every way preferable to a deposited cathode, much time and labor were expended by Mr. L. R. Vorce and myself on the production of flexible nickel sheets. As a chloride solution was in use in the plating baths, it was thought advisable to use a similar solution for the cathode deposits. Early experiments showed that pure nickel chloride gave such an intensely hard and brittle metal that it was difficult to strip, and, after repeated trials, a solution containing about 90 grams nickel chloride and 170 grams common salt per liter was taken as the basis of experiment. Working from this solution, some interesting experiments on the effect of acidity, heat, current density and solution density were undertaken.

The choice of cathode upon which to deposit narrowed down to copper, lead, tinned iron and block tin. Of these, copper was discarded as liable to foul the solutions. Tinned iron gave such a smooth deposit that the second plating would not adhere, while lead caused too firm adherence between cathode and deposit to be satisfactory. A graphited cathode of rolled block tin was in every respect found satisfactory. The sheet was prepared by painting an inch-wide border of P. & B. paint around the edges. Within this the tin surface was discolored by an exceedingly thin coating of the same paint, dissolved in bisulphide of carbon, or any other thinner. Over this discoloration fine graphite was rubbed, to form a stripping surface. As the nickel separates from this surface very readily, it was found necessary to scrape off the graphite for a width of about an eighth of an inch within the painted border, thereby leaving a bare edge, to which the deposit adhered.

On such a cathode small sheets, say, 6 inches square, which will be flat when stripped, are readily prepared. With sheets about 18 x 24 inches the difficulties are much greater, on account of the increased surface over which uniform conditions must be maintained. The first test made was for solution density.

DENSITY OF SOLUTION.

M solution, 70 grams $NiCl_2$, 180 grams NaCl per liter.
N solution, 90 grams $NiCl_2$, 180 grams NaCl per liter.
O solution, 110 grams $NiCl_2$, 180 grams NaCl per liter.

All solutions kept at 75° C.; cathode, 36 square inches; 60 ampères per square meter; 360 amperes used. All deposits were good, but sample M was the most flexible.

HEAT.

P solution, 70 $NiCl_2$, 180 NaCl at 70° C.
Q solution, 70 $NiCl_2$, 180 NaCl at 90° C.
R solution, 70 $NiCl_2$, 180 NaCl at 103° C.

The flexibility increased with the temperature. In practice, however, 70° C. was easiest to maintain.

CURRENT DENSITY.

A solution, 70 gram $NiCl_2$, 180 NaCl, 70° C., 32 amp. sq. m.
B solution, 70 gram $NiCl_2$, 180 NaCl, 70° C., 83 amp. sq. m.
C solution, 70 gram $NiCl_2$, 180 NaCl, 70° C., 116 amp. sq. m.
D solution, 70 gram $NiCl_2$, 180 NaCl, 70° C., 220 amp. sq. m.
E solution, 70 gram $NiCl_2$, 180 NaCl, 70° C., 270 amp. sq. m.
F solution, 70 gram $NiCl_2$, 180 NaCl, 70° C., 345 amp. sq. m.

A was gray and speckled, with dark spots; was flexible, but would not bend right angles; annealed well.
B was whiter, and fairly flexible; annealed well.
C was bright and white, flexible, and annealed well.
D, light gray, very smooth; annealed beautifully.
E, very white and smooth, and also annealed very well.
F, dark color; curled and cracked off.

ACIDITY.

G, same solution and temperature, 250 amp. $M^2$ neutral.
H, same solution and temperature, + 0.1 per cent. HCl.
I, same solution and temperature, — 0.2 per cent. HCl.

G was very white, smooth and flexible.
H, rough, light gray and covered with hydrogen points; was brittle, and would not bend to right angle.
I was dark gray to black, with hydrogen streaks, and very brittle.

We have, therefore, the following indications:
First. Neutrality of solution.
Second. Heat increases flexibility.
Third. Solution about 70 $NiCl_2$, 180 NaCl per liter.
Fourth. Current from 100 to 200 ampères per square meter.
Fifth. Efficient circulation.

These conditions have given in practice very fair results. All cathodes made in this way have, however, a slight outward curl, which curl increases with the current density. Cathodes about 18 x 24 inches, made at 60 ampères, would curl about 2 inches out of plane, while those made at 200 ampères would roll up into a coil. The curling was always anodeward and around the longer axis of the cathode, irrespective of the way in which the cathode hung in the bath.

Square cathodes curved either way—that is, about either central line—according to which way pressure was applied.

A test was made to determine the extent of curvature given by a certain current. This being established, an anode was curved to the same radius, and a cathode was fastened to a backing of the same, but reversed curvature. The plating was now performed in exactly the same manner as before. When the cathode had attained the desired thickness, it was stripped from the backing and, as was expected, sprang into a perfect plane surface.

This suggests the employment of a curved cathode to measure the intensity of surface tension of deposits under various conditions, and, as a matter of scientific investigation, such experiments would probably be productive of much valuable information.

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## PROF. F. HABER ON ELECTROCHEMISTRY IN THE UNITED STATES.

### I.

As was announced in these columns at that time, Prof. F. Haber, of Karlsruhe, Germany, visited this country last year, as a delegate of the German Bunsen Society for Applied Chemistry to the American Electrochemical Society. His society also asked him to report on the industrial development of electrochemistry in this country, and on the methods of teaching electrochemistry in our universities. The visit of Dr. Haber extended over a period of sixteen weeks. On his

return to Germany, Dr. Haber gave a summary of what he had seen in America, in a series of lectures held in various German cities before local sections of the Bunsen Society. We are glad to present to our readers in the following rather full abstracts of his lectures, which will no doubt interest many in this country. It is always of interest to learn how others see us, and this is enhanced in the present case by the prominent position which Dr. Haber deservedly holds among the electrochemical scientists of Germany.

Dr. Haber first pays his respects to all those who aided him while on his trip, to all his old and new friends in the United States, and to the American Electrochemical Society, which received him in a very cordial way.

He speaks enthusiastically of the impression which he had when the steamer entered the harbor of New York. "The beauties of nature may be more magnificent in other places, but nowhere have I seen a similar example of industrial activity. This impression grows in the inner harbor and forces aside any other sentiment when one enters lower New York, the forms and means of traffic there exceeding everything that is known to us in the old continent." He points out the differences in the industrial development in the European countries where the older type of culture exists, and in a new country like the United States. In the former the treasures with which they are endowed by nature no longer require to be discovered and an increase of wealth of the nation depends upon larger refinement of engineering skill and upon progress of scientific knowledge; it is a development "in depth," rather than "in breadth." The latter is the characteristic feature of the new country which is still able to apply the achievements of the older countries to the utilization of undeveloped wealth.

"How rapid and how original this development is, depends in the first place upon the character of the people. It is above all a question of self-estimation and enterprise. No nation has these virtues in a higher degree than the people of the United States. Its spirit of enterprise is the natural inheritance of their ancestors who, whatever might have driven them from their old homes, had the courage to build up new homes in a foreign country under strange and uncertain conditions. The self-estimation, however, of the individual man, as well as of the nation, is perhaps the most essential trait of the American character. It manifests itself in various forms: in the early independence of the youth; in the national sensitiveness which we often observe with surprise in the common people, as reflected in the daily press; in the opposition of any individual to official guardianship; in the ambition of the nation which wants to rid itself of its intellectual dependence on other countries. In my intercourse with widely-differing individualities among American chemists, nothing appeared to me so remarkable as their common tendency to prove and to have recognized the equal and independent standing of the industrial accomplishments of the United States as compared with the older successes of Europe. To recognize the value of these national virtues, it is sufficient to look at the neighboring country, Canada. On both sides of the political frontier there is a similar richness of treasures of nature, but the character of the nation which utilizes them with creditable alertness under the stars and stripes is missing beyond the frontier, and there is a great difference between the states of the industrial development in the two countries."

The enormous development of civil, mechanical and electrical engineering in the United States has been due to the dimensions of the natural conditions and to the lack of manual labor; the problems set by the conditions of the country, such as the distances to be overcome, etc., were so much greater in the United States than in Europe, that these branches of engineering have long ago become independent of Europe, and have undergone a development which in some respects sets an example to Europe. It is different in chemistry. In a young country, rich with metals as the United States is, the industrial development first requires only a relatively small knowledge of chemistry, as absolutely necessary for metallurgical enterprise. Dr. Haber remarks that among American chemists the faculty of speaking or understanding German is nearly universal, but is very restricted among mechanical and electrical engineers. He considers this as a symptom showing the influence of Germany upon the development of chemistry in the United States.

He points out, however, that the period of the general influence of Germany on the chemical industrial development in the United States is now about passed. While he thinks that in organic chemistry Germany will retain the lead in the world, all the branches of inorganic chemistry in the United States have become or are becoming independent. Metallurgy has long become independent, and in the size of plants, the development of machinery and the output of metals, it has generally surpassed Europe. "In the inorganic chemical industries there is felt the coming of a new era. The deplorable, old, imperfect installations in this branch which a stranger sees with surprise in a country provided with the most conspicuous modern installations in metallurgy, and mechanical and electrical engineering, are quickly changed or are replaced by new installations." This change is indicated economically by a decrease of the prices of the products of inorganic chemistry which is always accompanied by an increase in output and sale.

Abstracts are given of statistical tables, prepared by Dr. Munroe for the last census of the United States, and attention is called to the fact that 1,740 chemical firms (with more than 2,280 plants) in the United States employ only 276 chemists. Of course this is not the total number of chemists in the United States. This number does not comprise the numerous chemists in the metallurgical plants, nor the independent consulting chemists, nor the pharmaceutical chemists, nor the professors of chemistry at universities. But the above figures show how different the Americans and the Germans look at the operation of a chemical plant. In the United States the chemical plant is a fully developed mechanism, the operations being carried out with mechanical regularity, although perhaps under a certain control by analysis; the American manufacturer does not consider research work as a necessary supplement to the regular operation of his plant, while the German manufacturer generally employs a certain number of chemists who do research work, the results of which are not felt by immediate improvement of the income of the factory, but only by possible results, hoped for in the future.

Dr. Haber then discusses at length the study of electrochemistry and of physical chemistry in American universities. A general comparison of American and German universities is given, and as instances of the study of chemistry on American universities some statistical notes are given on Harvard University, Leland Stanford, Jr., University, and the Case School of Applied Science, in Cleveland.

He finds that a characteristic difference exists between the requirements for entering a university in Germany and one in the United States. He says that the student entering a university in the United States has had by far less scientific education than in Germany. On the other hand in American boys a certain technical intuitive power is developed to a remarkable and much greater degree than in German boys; in this respect the workshops in high schools, manual training schools and universities, have an important influence.

In summing up his comparison of American and German universities Dr. Haber draws the following conclusion: From the German point of view, the education in chemistry in American universities appears "superficial and practical;" it is called superficial in view of the great number of students whose education ends with the degree of bachelor. The remedy against superficiality is the growing recognition of the importance of post-graduate work. From the American point of view, the education in chemistry in German universities appears "thorough and impractical." It is impractical because

the intimate connection between German universities and the industrial development of inorganic chemistry has been lost. Dr. Haber emphasizes the importance of physical chemistry to the inorganic chemist; physical chemistry is not a special branch of chemistry, but represents the only general method by which the chemist should think.

Dr. Haber then sketches the industrial development of electrochemistry in the United States. After some general statistical remarks he describes his route in his trip through the States: New York, Philadelphia, Niagara Falls, Sault Ste. Marie, Anaconda, Trail, B. C., Seattle, San Francisco, Denver, Chicago, New England States, Penn Yan, N. Y., New York, Kanawha Falls, W. Va., Baltimore, Philadelphia.

Concerning the situation in California, Dr. Haber shows how the high price of coal has caused the enormous development of long-distance electric transmission. He also points out that the situation has been somewhat changed in recent years by the increased use of California oil as fuel. For extended electrochemical industries in California he believes the cost of electric-power to be still too high. Moreover the country is not yet "ripe" for electrochemical industries, although there are good prospects for electrolytic copper refining in the northern part of the State, and for the electrolytic winning of tin from scrap tin in the southern part; as the price of zinc is high, the precipitation of gold from cyanide solutions by means of the electric current also appears promising.

Dr. Haber then makes some remarks on the new Moebius process for gold refining, as it has been used in Denver, and on Swart's and Blake's separation of metals by electrostatic means. In then passing to a general discussion of the industries at Niagara Falls, he begins with some critical remarks on water-powers.

The rapid development of some electrochemical industries, especially of the manufacture of aluminium, has been intimately connected with the development of water-power. But it would be wrong to generalize this statement by assuming that the enormous development of industries and engineering in general in the United States has been due to water-power developments. The increase of steam-power has been much greater since 1870 than the development of water-power. Dr. Haber characterizes the United States as the country of cheap coal. Since the last three years, the United States leads the world in the production of coal. Of 780,000,000 metric tons mined 1901 in the world, 33.9 per cent. were mined in the United States, 28.3 in England, and 19.5 in Germany. Besides the cheap price of coal, there are also low freight rates.

Concerning the cost of generating electrical energy by steam-power he makes the following remarks: "Very often the cost of the electric horse-power hour, produced by steam-power, is given at 1 to 1.25 cent." He emphasizes that this will be about right for a greatly varying load curve and discontinuous operation, but that for absolutely continuous operation with uniform load the cost is much smaller, and may be as low as 0.25 cent per horse-power hour. This latter figure is given as the cost of power generation by the Dow Chemical Co., in Midland, Mich. Dr. Haber points out that this plant is of peculiar interest, as it is an example of the electrolysis of a brine solution, in which only the anodic chlorine is utilized, while the cathode liquid, containing alkali mixed with salt, is wasted.

Canada is even richer than the United States in water-powers which can be cheaply developed. The reason why Niagara Falls has become the prominent centre of electrochemical industries, although the price for power is not very low, is that it is very favorably situated for shipping freight to different parts of the country. For similar reasons Sault Ste. Marie is important, although he believes that the power available at this place is not sufficient to expect a second electrochemical center there like Niagara Falls.

Dr. Haber then gives data concerning the amount of power used by the different electrochemical concerns in Niagara. He thinks that for the power used in the two plants of the Pittsburg Reduction Co., 15,500 horse-power is nearer the truth than 10,500 as given by Dr J. W. Richards; the company itself decline to give the exact figure. Dr. Haber then gives descriptions of the processes used by the Union Carbide Co., and the Pittsburg Reduction Co. at Niagara; the manufacture of ferrochromium by the Wilson Aluminium Co., in Kanawha Falls, W. Va., the manufacture of silicon copper by the Cowles Electric Smelting and Aluminium Co. in Lockport; and the Acker process in operation at Niagara. The success of the Acker process is said to be technically perhaps the most unexpected; the voltage is higher than in other process, but the current efficiency is better than in any other known process for alkali and chlorine. "The durability of the apparatus is said to be fully satisfactory, but it cannot be denied that in this important point absolutely sufficient data are not yet available. Assuming that the durability will be found to be satisfactory in the future, the process would have all chances of becoming the standard process on account of its simplicity and elegance, if there was not the high power consumption. In any case the success of the Acker Bros., who, in a work of eight years succeeded in passing from laboratory experiments over to a plant of 45 furnaces, consuming 3,000 electric horse-power in continuous undisturbed operation, is to be considered as a remarkable technical achievement."

A summary of the balance of Dr. Haber's lectures will be given in our next issue.

## ELECTROCHEMICAL ANALYSIS.

By Ivar Iuel Moltkehansen.

It is sometimes found in books treating with the subject of analysis by electrolysis, that the quantities of acid, etc., required for the analysis or for the separation of metallic compounds are given in percentages of this acid. On figuring out these data one finds, however, that these percentages do not refer to the concentrated substances. Still, one looks in vain for any statement elsewhere in the same book or essay as to the concentration of the said reagents, as a general statement is not to be found, and sometimes apparently solutions of varying concentrations of the same compound are referred to on different pages of the same book. This defect is even to be found in the classical research by Luckow, treating with the determination of lead as $PbO_2$ at the anode (*Zeit. f. Anal. Chemie*, Vol. 19, page 1). But as in electrochemical analysis it is of the highest importance that the concentration of the electrolyte be known, the difficulties arising from these omissions require investigation.

To illustrate, I met with these inaccuracies, as I sometime ago took up the problem of separating lead and manganese by electrolysis according to Neumann. The electrolyte he used was said to contain about 20 per cent $HNO_3$, but the concentration of this nitric acid is not mentioned (*Zeit f. Elektrochemie*, 1895, Vol. 2, page 253; *Chem. Ztg.*, 1896, Vol. 20, page 383). On examination it was found, that Neumann in this case does not refer to percentages $HNO_3$, but then to an acid of which concentration? Further Neumann only claims that this method gave him "approximately correct results."

It seemed for these reasons desirable to test his statements more closely by first finding out the quantity of acid necessary for the separation, and secondly testing the accuracy of the method. The principle of the separation of lead and manganese is to keep the manganese in the solution as permanganic acid and to precipitate the lead alone at the anode as lead peroxide. This is obtained by using a high current density and high concentration of acid and by heating the electrolyte. I succeeded in carrying through the exact separation of lead and manganese by greatly increasing the amount of acid in the solution. It was not found that the $PbO_2$ was more firmly deposited on the anode, if the electrolyte was heated to

70 C. (178° F.), before the current was turned on, and on starting the precipitation the Bunsen burner was taken away. The temperature would then slowly go down in thirty-five to forty minutes from 60 to 65° C. A separation is not possible when equal quantities of lead and manganese are contained in the electrolyte. According to my researches in this direction, it was found that the proportion at the lowest must be as 2 Pb to 1 Mn, but it is preferable to have a still greater excess of lead: 3 to 7 Pb to 1 Mn; 150 cc solution should not contain above 0.03 g. Mn. I could still analyze a solution with 0.04 gr Mn by adding a few cc oxalic acid at the critical moment, as shown by my analysis published in the *Chem. Zeitung*, Vol. 25, page 37. This method will be of importance for the analysis of many galenas containing small quantities of manganese.

The following conditions have proved favorable for carrying out the separation of lead and manganese according to my researches:

First. When the solution does not contain over 0.03 gr. Mn, the analysis should be started at 70° C. and 2 ampères for an anode area of 150 square centimeters the electrolyte should contain 25 to 27 cc nitric acid (1.42) in 150 cc, the total volume of the electrolyte, or 55 to 60 cc of the acid 1.19, corresponding to 18 per cent. pure $HNO_3$. The electrolysis is completed in thirty-five to forty minutes, and it is of importance that the current should not be allowed to flow unnecessarily long.

Second. If there is more manganese (up to 0.04 gr to 150 cc) in the solution, satisfactory results are obtained by increasing the amount of nitric acid (1.42) to 35 cc by 2 to 2.5 ampères, but it is preferable in this case to use 25 to 27 cc $HNO_3$ (1.42) and add a few cc oxalic acid as soon as flakes of manganese hydroxide form in the electrolyte in order to bring these into solution again.

The red color of the solution is taken away by adding the oxalic acid, and it is necessary not to break the current until the strong red color is again perfectly regenerated. The whole analysis is finished in thirty-five to fifty minutes.

It is of importance to wash the anode very well with water before drying and weighing it.

I might further remark that the first method may be recommended for the regular determination of lead even without any impurities in the electrolyte, as I often found a slight precipitate of lead on the cathode, when according to the regular formula less nitric acid was added to the electrolyte. As a further advantage of my method may be considered that the entire analysis is brought to an end in forty-five to fifty minutes, instead of the seventy to seventy-five minutes required for the analysis at a lower current density in a weaker acid solution.

## CONDITIONS OF PROGRESS IN ELECTROCHEMISTRY.

In the following we abstract the conclusion of Dr. J. W. Richards' presidential address to the American Electrochemical Society the first part of which was given on pages 324 and 325 of our May issue:

### IV. INCREASING APPLICATION TO INDUSTRIAL NEEDS.

"In order not to become a mere code of observed and classified facts, a thing to interest men by its intrinsic perfection, but no other earthly use, a science must find practical applications which increase the comfort, pleasure or wealth of mankind. In this field electrochemistry is in no manner lacking; it abounds in notable achievements. If that man is a benefactor of the race who, figuratively, makes two blades of grass grow where but one grew before, then the practical electrochemist certainly takes high rank among the benefactors of mankind. The whole circle of human industry consists in utilizing the fleeting value of the perishable capacity to labor, linking it with natural forces, and thus turning into valuable products natural crude material. The items concerned are crude material, power, brains and industry. Power alone is apt to be regarded as the first desideratum for the success of electrochemical processes, but knowledge, thinking power and industry are more primary factors. Given these, crude materials to work with will be found on every hand, and power sufficient will be created if it is not to be found."

The author discusses the problem of cheap power. He refers to the developed water power and to the still undeveloped surplus power from blast furnaces, obtainable by gas engines. There are scattered over the United States, in some of our most flourishing industrial centers, undeveloped powers which aggregate over 1,000,000 horse-power, which can be developed at no more cost than the average water-power, and can be generated just at the spots where they can be most favorably utilized.

This increasing development of power and its increasing application to industrial purposes is best promoted by the intimate and cordial co-operation of theoretical with practical electrochemists. This is attained by many agencies, but the most potent are research companies and our American Electrochemical Society.

### V. AN INCREASING DISSEMINATION OF THE LITERATURE AND FACTS OF THE SCIENCE.

"No modern science can progress if it adopts the mediæval practice of the alchemists, and carefully guards its wisdom for the exclusive use of the initiated. Widespread dissemination of the literature of our science, not only among our own fraternity, but amongst educated people in general, and even down to the rising generation of expectant scientists, is as necessary to our progress as is the recruiting of the human family to the preservation of the race."

The author discusses in detail and at length the influence which the transactions of technical societies, technical journals, monographs and text-books can have on the progress of the science and industry.

### VI. AN INCREASING VISION OF THE POSSIBILITIES OF THE SCIENCE.

"If we ask the student of electrochemistry why he chooses this for his life work, he will possibly reply that he has been advised, by counsellors in whose judgment he relied, that this is a most promising field for his activities. More probably he will answer that, by reading himself some of the literature of electrochemistry, he became attracted by the novelty of what was being achieved, and wished to take part in a science with such a promising future. In either case the knowledge of what is and the vision of what may be in this almost virgin field of human endeavor is the magnet which draws recruits and adds to the working forces in our ranks."

"If we ask the enthusiastic worker in his laboratory what is the principal force keeping him at his work, which ever incites to fresh activity and lightens labors which might otherwise easily become tedious, the ready reply is that there is so much to do, so much to find out, so much promise of achieving great things, that he would be made of very dull stuff indeed who would not be enthused thereby. The ever-widening vision of an ever-widening field is the reward and the inspiration of every honest worker, and is the mainspring of the mechanism whose working means progress to our science."

"In every field of human endeavor, for the teacher in his class room, the writer at his table, the editor at his desk, the workman at his labor, the investigator at his task, the chief incentive to happy, productive work is the vision and the promise of what may be attained. Without that vision life would be dull indeed."

"To the seers of old was ascribed the wisdom of the ages, and, with the prophets, they guided humanity to higher and nobler things. The see-ers saw before them and before humanity the things which might be, the promise of the future, the possibilities for development which lay before the race. They gave new life and hope to mankind by proclaiming the possibilities which might be achieved."

"In like manner each one of us is inspired and encouraged,

nerved to high endeavor and imbued with the spirit to do and to achieve by the sight or vision of the possibilities of electrochemical science. Some may have the vision but dimly; others see clearly and far into the future which yet lies so close before us, but each is privileged to share in part the vision of his neighbor."

"If there is, therefore, one thing which an electrochemical society, such as ours, achieves of more superlative worth than any other thing, it is the resultant enlargement of vision which comes to each of its members, mainly and chiefly from the interchange of thought, the sharing of ideas, the communication of insights into the possibilities of the science resulting from our semi-annual meetings. Does not each one of us go away from these meetings feeling that he has been sharing in the visions of all his electrochemical brethren, and with his mind overloaded with suggestions, thoughts and ideas of what may, can and will be done in the near future that he wishes he had a dozen lifetimes at his command, in order to work out the realization this plentitude of ideas? Such is the zeal and ardor which our meetings engender in a high degree, resulting from listening to papers and discussions, by conversations, by simple handshakes and seeing our friends, and by breathing the invigorating atmosphere of our assemblies."

"Let us, then, you and I, one and all, see it as our privilege, as well as our duty, to promote in every way the interest, the attractiveness and the scientific atmosphere of these meetings, for they are, if we will but realize it, the elixir of life to the development of electrochemistry in America."

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl.

## Electric Furnaces and Furnace Products.

*Electric Furnace.* E. A. Sjoestedt, Sault Ste. Marie, Canada. Assignor to the Lake Superior Power Co. Patent 726,364, April 20, 1903. Application filed September 20, 1901.

The specification describes an electric furnace for the smelting of ores, especially iron ores, and the object of the invention is said to be the construction of an electric furnace that will withstand for a reasonable time the great heat developed, have apertures for the escape of gases of combustion, for tapping slag and metal and stoking holes for breaking up the slag crusts, etc. The furnace is shown in cross section in Fig. 1. It consists of a cast iron body B, and a bottom frame C, with an interior refractory lining $B^cC^c$. The lower parts of the sides and ends and the bottom frame are constructed with water jackets *b*, *c*. The bottom is removable and the furnace body is raised considerably above the floor by legs F, in order to make it possible to run a ladle car under it, which travels on the rails *g*. H is the slag notch and I the tapping hole. The upper electrode K, consists of a battery of square carbon pencils, and is introduced through the cover D. The bottom electrode L is laid on the refractory lining C, and makes contact with the base of the furnace, where the current is introduced, by means of the frame C. In starting the furnace for smelting iron ores the electrode K is brought so close to the bottom L, that an arc is struck. The powdered ore and flux are then fed in and it is said that a slag is soon formed, which acts as an electrode and thus protects the bottom carbon. As the ore is reduced, the metal sinks to the bottom and the electrode is gradually raised. The slag is drawn off and the metal tapped as required.

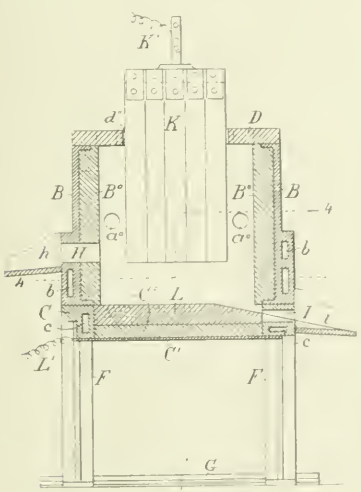



FIG. 1.—ELECTRIC FURNACE

*Electric Furnace.* J. M. Carrere, New Brighton, N. Y. Patent 726,860, May 5, 1903. Application filed May 22, 1902.

This furnace is intended for the treatment of various materials, such as ores, cement, rocks, etc., for the reduction, melting, etc., by the current. It looks much like an ordinary rotary cement kiln and is similarly inclined at an angle, though it may be placed horizontally if desired. It has appliances for being rotated. The body of the furnace consists of an iron shell, which is by preference made in two parts and furnished with the necessary stiffening appliances. It is lined with graphite or other substances of low electric conductivity, and the lining is throughout insulated from the shell by an intervening layer of asbestos. The ends of this shell are closed by iron caps, which are likewise furnished with a layer of graphite insulated by asbestos. The ends of the shell extend between and pass into the caps. The cap ends are provided with contacts in such a manner, that the latter make electrical contact with the graphite lining of the cylindrical shell. By these contacts a current may be introduced, as the shell revolves, into the graphite lining, which can by this means be heated to any desired temperature. In addition, there are provided carbon electrodes introduced into the cylinder, from opposite ends, passing through a bushing in the respective caps. These electrodes are longitudinally movable in the bushings, and by this means the arc produced between them may be established and adjusted to any desired point within the cylinder, and consequently a maximum of heat established at that particular point. It is claimed that by this arrangement, the time during which the materials to be treated are brought into contact with the heated surface may be precisely regulated, and that the heat produced in the furnace may be either uniformly distributed over the surface of the lining or may be concentrated at a given point, or the surface of the graphite lining may be uniformly heated, and at the same time an intense heat generated centrally at a given point within the cylinder. The upper end of the cylinder receives the charged materials, while the treated matter is discharged at the other end. Either alternating or direct current may be used. The surface of the interior of the furnace is brought to incandescence by first establishing the arc and then drawing it the length of the

cumulator, meanwhile leaving the independent current through the lighting also available.

*Method of Utilizing Calcium Carbide Refuse and Product Thereof.* G. E. Cox, Niagara Falls. Assignor to Union Carbide Co. Patent 727,095, May 5, 1903. Application filed September 3, 1902.

The inventor claims to have discovered a method for fusing the calcium carbide refuse and converting it again into the commercial product. This refuse is largely carbide dust from the breaking up of the large blocks, mixed with partly or wholly unreduced material. This material cannot be used in the acetylene generators, as it floats as dust on the surface of the water until enough has accumulated to cause it to sink, and then a very rapid evolution of acetylene takes place which might injure the generator. If an attempt be made to fuse this refuse in the ordinary carbide furnace, it is soon found that it will not work, owing to the high conductivity of the material, which causes the electrodes to become short-circuited and destroyed. The heat generated is not distributed properly in the furnace, but the electrodes and connections become unduly heated. Other methods for utilizing this refuse were also not successful. The method applied in the present instance consists in treating the refuse in a suitable electric furnace, that is to say in one, in which the electrodes are separated much farther than they are in the ordinary carbide furnaces, using coke and lime. Electrodes of graphite are used in preference to ordinary carbon electrodes. It is stated that the conductivity of the electrodes and the charge of refuse is so great, that it is necessary to use a much lower voltage than in the ordinary carbide furnace. For example, a furnace for refuse using the same electrical energy as a furnace fed with lime and coke may be operated at one-half the usual voltage and with double the amperage, this ratio however being variable and dependent upon various conditions. Thus a furnace, which is built for refuse is quite unsuited to a charge of coke and lime, while under the conditions mentioned, it works quietly and the refuse fed into it forms a solid ingot of carbide, which is broken and packed as usual. It is stated that the heat generated by the passage of the electric current through the furnace and which serves to raise the charge to a temperature at which it will melt into an ingot, may be due either to the resistance of the refuse or to arcs sprung between the ends of the electrodes and the refuse, or to both.

### Apparatus and Processes for the Electrolytic Production of Metals and Compounds.

*Electrolytic Manufacture of Chlorates and Perchlorates.* Pierre Lederlin, Chedde, France. Patent 727,813, May 12, 1903. Application filed July 11, 1902.

The inventor claims: "A method for the manufacture at a high constant yield of chlorates and perchlorates by electrolysis of a chloride solution, with the previous addition of a corresponding neutral chromate, consisting in maintaining the electrolyte during the electrolysis in a non-alkaline state by the addition of hydrochloric acid." The approximate proportions of the neutral chromate and the saline electrolyte (chloride solution) is stated to be 2 grams of neutral chromate to 20 grams of the saline electrolyte. In this manner, the inventor states, he causes, owing to the acidity, the favorable property of chromic acid to entirely and continually compensate the cathodic reduction, which is one of the causes for the loss of yield. A yield of 0.55 to 0.50 grams per ampère hour is claimed to be obtained with NaCl, corresponding to 84 per cent of the theoretical yield.

*Art of Producing Hydroxylamine.* Julius Tafel, Würzburg, Germany. Patent 727,025, May 5, 1903. Application filed February 24, 1902.

The object of this invention is to produce hydroxylamine by electrolytic reduction. The inventor claims to have discovered, that hydroxylamine may be obtained in good quantities by electrolysis under suitable conditions of a solution, containing an acid electrolyte in addition to the nitric acid to be reduced, it being therefore possible to produce hydroxylamine directly from nitric acid on a commercial scale. It is necessary to carry out the reduction while well cooling, and care must be taken to stir the electrolyte quickly and uniformly. The possibilities of an excess of nitric acid must also be avoided. The nitric acid is therefore added slowly in the proportion in which it is being used, so that it is supplied only at one concentration, just sufficient for the most advantageous employment of the current. As cathode material mercury or an amalgamated cathode are specially suitable, although the reduction may also be carried out by the employment of a cathode of lead, tin, silver, nickel, bismuth or copper. Other by-products of the reduction of nitric acid are produced in more or less subordinate quantities, according to the material of the cathode used. The methods of procedure are described as follows:

(1.) Reduction of nitric acid to hydroxylamine in sulphuric acid solution. An electrolytic cell is separated into an anode chamber and a cathode chamber by a diaphragm. The cathode chamber is filled with 6 kilograms of 50 per cent. sulphuric acid, the anode space with the same 50 per cent. sulphuric acid. Each chamber of the cell is provided with means for cooling. The cathode consists of well-amalgamated lead, while the anode is formed of pure lead. A current of 60 to 120 ampères per square decimeter is now sent through the bath, both spaces of the cell being well cooled. Thereupon 2 kilograms of a 50 per cent. solution of nitric acid are added slowly to the bath by a dropping apparatus, so that always a slight evolution of hydrogen is just noticeable at the cathode. At the same time the cathode solution is powerfully stirred. During the operation it is advisable to keep the temperature of the bath at about 20° C. The reduction is carried out until a test of the cathode liquid proves there is no further nitric acid in it. The resulting hydroxylamine is then isolated from the reaction liquid as chlorhydrate or sulphate.

(2.) Reduction of nitric acid to hydroxylamine in hydrochloric acid solution. In carrying out this process, the same steps are employed as in the above, with the exception, however, that the cathode chamber is provided with 6 kilograms of about 20 per cent. solution of hydrochloric acid. It is preferable to employ a tin cathode or equivalent cathode, or if a cathode of indifferent material is used, then some spongy tin should be added to the bath in the proportion of about 10 grams per liter.

*Manufacture of Camphidon.* Julius Tafel, Würzburg, Germany. Patent 727,024, May 5, 1903. Application filed April 3, 1902.

*Camphidin and Method of Preparing Same.* Julius Tafel, Würzburg, Germany. Patent 727,026, May 5, 1903. Application filed August 13, 1902.

The two inventions relate to the manufacture of derivatives of camphoric acid, and more particularly to the preparation of products richer in hydrogen than imido-camphoric acid. The inventor states that he has found, that by subjecting imido-camphoric acid, which has the formula $C_{10}H_{15}NO_3$, to electrolytic reduction, a new body poorer in oxygen and richer in hydrogen is obtained, which new body he calls "camphidon." The reaction proceeds in a manner similar to that involved in the production of pyrolidon from succinimide. If the reduction in the latter case is continued somewhat further, some pyrolidin is concurrently obtained. In a similar manner a higher hydrated body, which is called by the inventor "camphidin," is formed together with the camphidon if the reduction is carried further. The two compounds are to be used for pharmaceutical purposes and are prepared in the following manner: 1 kilogram of imido-camphoric acid is dissolved in sufficient sulphuric acid of 65 per cent. strength to make 10 liters of solution, which is then poured into the cathode com-

partment of an electrolytic cell or bath. The anode compartment having been similarly charged with dilute sulphuric acid, the current is passed through the cell for three and a half hours, the current having a concentration or strength of 120 amperes per liter of the electrolyte, and the cathode surface being 10 square centimeter per liter of electrolytic bath. The cathode employed by the inventor is a lead cathode prepared by him according to the method given by him in the *Berichte der Deutschen Chemischen Gesellschaft*, Vol. 33, page 2,209. After the reduction has been completed, the major part of the sulphuric acid is removed by precipitation with calcium carbonate, filtering and extracting the resultant camphidon from the filtrate by repeatedly shaking with chloroform. Upon thereafter evaporating the chloroform, the camphidon is left as a soft crystalline mass, having a weak or faint camphor-like odor. From the acid filtrate, from which the camphidon has been removed, in the manner indicated above, the new compound camphidin is obtained by first supersaturating with an alkali, such as soda lye and then driving off the camphidin with steam. It is thus obtained as a light, soft, crystalline mass, having an intense camphor-like odor. Its composition is indicated by the formula $C_9H_{15}N$. At 180° centigrade it melts to form a colorless liquid, which distils without decomposition at 209° centigrade. It is soluble with considerable difficulty in cold and hot water. It is distinguished from camphidon by its volatility under the influence of steam or aqueous vapor and by its strong basicity. The above methods are interesting examples of the use of the reducing effect of the current.

*Production of Permanganates.* Wilhelm Hickmann, Frankfort-on-the-Main. Assignor to Society Chemische Fabrik Griesheim, Electron. Patent 727,702, May 12, 1903. Application filed March 3, 1903.

This invention covers a method for the obtaining of such permanganates, such as calcium permanganate, which are not readily obtained by the metathesis of suitable salts and alkali permanganates. It has been found that these reactions, which cannot be obtained in a purely chemical manner, take place, when mixtures of solutions of alkali permanganates or manganates are, together with the oxygenated or halogen compounds of the metals of which it is desired to obtain the permanganates, subjected in a suitable manner to the action of the current. The preparation of calcium permanganate is carried out as follows: (1) An electrolytic cell is employed, the anode compartment of which is separated from the cathode compartment by a diaphragm or other suitable means, so that the anode liquid is prevented from mixing with the cathode liquid and a reduction of the permanganate is avoided. Both compartments are closed at the top and provided with outlet-pipes through which the gases escape separately. The cathode compartment is filled with diluted potash lye and the anode compartment with a saturated solution of potassium permanganate, which is maintained in the state of saturation by means of sieves suspended in the liquid, which are filled with potassium permanganate. Washed calcium hydroxide is introduced into the anode compartment, this being preferably done gradually, as the operation is proceeding, so as to prevent the diaphragm being stopped. If now a current is passed through the cell, the potassium ions migrate into the cathode compartment, where caustic potash is formed in the usual manner and hydrogen given off. The $MnO_4$ ions remain in the anode compartment, and from these oxygen is evolved, while at the same time permanganic acid is formed, which, as soon as it forms, combines with the calcium hydroxide held in suspension, thus forming calcium permanganate. When the calcium salt has reached a certain concentration, it is advisable to interrupt the electrolysis and to separate by crystallization the potassium permanganate that is still remaining in the anode liquid. (2.) When calcium chloride is used instead of calcium hydroxide, the cathode compartment of the apparatus is filled with a saturated solution of potassium chloride. The anode compartment contains a saturated solution of about 100 kilograms of potassium permanganate, to which are added 20 kilograms of calcium chloride. Sieves containing potassium permanganate are arranged in the anode compartment in the usual manner. Under the influence of a current, of 2 or 3 amperes per square decimeter of electrode, Cl is yet free at the anode, while the K ions travel into the cathode compartment. It is stated that the corresponding quantities of Ca (or $CaCl_2$), and $MnO_4$ ions remain in the anode compartment and combine together to form calcium permanganate. The influence of the OH ions, which migrate in a smaller number into the anode compartment and might give rise to an intermediate formation of hypochlorous acid or chloric acid, need not be taken into account, as these substances are said not to be very stable under these circumstances. The electrolysis might be continued until the cathode compartment contains a quantity of potash lye corresponding to the amount of calcium chloride used, but it is preferred to stop the operation before this stage is reached. The yield in calcium permanganate is stated to correspond to the amount of caustic potash obtained. The calcium permanganate is obtained from the anode liquid by fractional crystallization.

### STORAGE BATTERIES.

*Storage Battery.* R. N. Chamberlain, Depew, N. Y. Patent No. 725,218, April 14, 1903. Application filed August 13, 1902.

The object of the invention is to provide a covered tank, jar or receptacle of simple and inexpensive construction which will effectually prevent the wasting of the electrolyte by evaporation; will return the escaping moisture to the electrolyte; will prevent the formation on the cover of an acid conductor across the battery plates or cells, and will afford easy access to the cell for the purpose of taking hydrometer and temperature readings. Claim No. 1 reads: "The combination with a tank or receptacle provided with a bottom, side walls and end walls, which extend upwardly above the tops of the sides walls, of battery plates arranged in said receptacle and provided with necks which project laterally over said side walls, and a cover for said receptacle, which is supported by said end walls."

*Secondary Battery Electrode.* J. Hahmann, Berlin, Germany. Patent No. 724,856, April 7, 1903. Application filed July 19, 1902.

The accompanying Fig. 2 shows the electrode proposed by

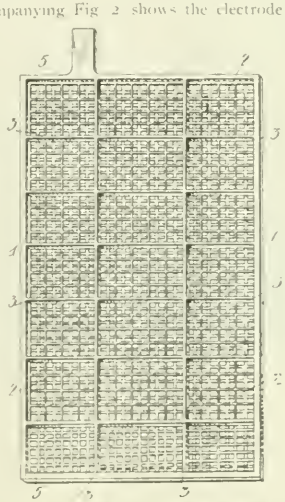


FIG. 2.—STORAGE BATTERY PLATE.

the inventor. It is composed of an oblong frame 1, which is

molded in box shape, with open top and a reticulated bottom surface 2. This bottom surface is very thin, and is stiffened by intermediate bars 3, which divide the plate into compartments. The cross bars 3 are flush with the border of the frame. Into the basin-shaped inclosure, formed by this frame and the reticulated bottom, the active material is packed and retained therein by a reticulated cover plate, which fits on the base frame and is soldered to it. The base plate, with its reticulated bottom and cross bars, and the reticulated thin cover plate are cast of an alloy of lead and antimony.

*Electric Accumulator.* A. Schmidt, Predari, Weimar, Germany. Patent No. 724,619, April 7, 1903. Application filed July 24, 1902.

The invention consists in providing special active masses for the negative and positive electrodes. The active mass for the negative electrodes is composed of a mixture of lead oxide, red lead, calcium hydroxide and alkali triosulphate; two parts of lead oxide, one part of red lead, one-twentieth part of calcium hydroxide and one-twentieth part of sodium thiosulphate having been found to give good results. The active mass for the positive plate is made of one part lead oxide, two parts of red lead and about one-twentieth part of spongy lead. This latter is preferably prepared by immersing several plates of lead in a solution of sodium thiosulphate of 1.07 to 1.12 specific gravity and passing an electric current. The active masses thus obtained are kneaded to a magma with dilute sulphuric acid, and then applied to the plates in the usual manner. The plates are preferably formed in a solution of glauber salt, of a specific gravity of 1.09 at a temperature of 25° to 30° C. The formation takes from two to three hours, and the formed plates may be used with the usual electrolytes; but the electrolyte best fitted for them is sulphuric acid to which an alkaline thiosulphate has been added. Sulphuric acid of 1.14 specific gravity, with an addition of sodium thiosulphate solution of 1.04 specific gravity, has been found suitable, the proportions being, preferably, two volumes of sulphuric acid and from one-half to one volume of sodium thiosulphate solution. This liquid, which is at first turbid, becomes clear when the acumulator is first charged and then remains clear.

MISCELLANEOUS.

*Electrical Process of Extracting Sugar.* Botho Schwerin, Berlin, Germany. Patent No. 723,928, March 31, 1903. Application filed November 15, 1901.

The invention relates to the process of extracting sugar by acting with the electric current upon disintegrated wet saccharine material which is placed between a negative elec-

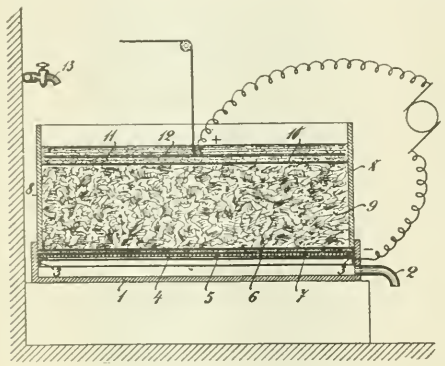


FIG. 3.—ELECTRO-ENDOSMOTIC TREATMENT OF SUGAR.

trode pervious to liquid and a layer of water separating the positive electrode from the saccharine material. The apparatus used for carrying out the process is shown in Fig. 3. A wooden box 1 of square shape, open at the top, is provided at its bottom with an outflow 2 for the sugar solution. Near the upper edge of the box are fixed at the inside supports 3 for a layer of wire gauze 4 and a layer of carbon 6, which is held between filter cloths 5 and 7. When the wire gauze and the carbon layer are placed, a frame 8, preferably constructed of wood, is inserted, closely fitting into box 1, so as to firmly clamp the wire gauze, filtering cloths and carbon layer between its lower edge and the supports 3. The frame is then filled with the saccharine material 9 up to a certain distance from its upper edge; the material is covered with a filtering cloth 10 and a mixture of water 11, and an earthy compound or compounds—for instance, calcium carbonate or magnesium oxide—is poured on top of it. A metal plate 12, serving as anode, is then suspended in the water. The wire gauze 4 serves as cathode. It is claimed that by causing the liquor to pass through a layer of finely-divided carbon, preferably animal charcoal, the albuminous matters dissolved in the liquor are caused to separate out upon the surface of the carbon layer, and that directly a concentrated, pure and almost colorless solution fit for crystallization is obtained without the necessity of special costly apparatus. Another improvement is claimed to result from suspending finely-powdered earthy compounds into the water surrounding the anode. These oxides or carbonates are stated to react with the acids that appear at the positive electrode to form salts, which, for the greater part, are insoluble in water. The anode is thus protected against decomposition, and the water is prevented from being infected with substances which might diffuse back into the saccharine material, with the result of producing invert sugar or otherwise impurifying the sugar solution.

## CURRENT NOTES.

University of Wisconsin.—We have received Bulletin 67 of the University of Wisconsin, which contains very neat illustrations of the buildings and surroundings of the University.

American Institute of Electrical Engineers.—The annual business meeting of the American Institute of Electrical Engineers was held on May 19th in New York City. As the result of the annual election Mr. Bion J. Arnold was declared president. The summer convention of the Institute will be held at Niagara Falls in July.

American Electrochemical Society.—At the meeting of the Board of Directors, held at Philadelphia on May 9th, the following gentlemen were elected members of the Society: J. J. Kennedy, New York; M. Temple Taylor, Savannah, Ga.; Archibald Meldrum, Savannah, Ga.; Charles D. Chasteney, New York; Howard W. DuBois, Philadelphia, Pa.; Joseph P. Devine, Buffalo, N. Y.; J. S. Crider, Cleveland, Ohio; Herman Poole, New York; C. E. Doolittle, Aspen, Colo.; S. Lawrence Bigelow, Ann Arbor, Mich.; Charles B. Dudley, Altoona, Pa.; Emanuel Stein, New York; William L. Nadolsky, New York; E. H. Whitlock, Cleveland, Ohio; Arthur Benjamin Frenzel, Denver, Colo.; F. Warren Smith, Los Catos, Cal.; E. A. C. Smith, Baltimore, Md.; Hans A. Frasch, New York.

Cornell University.—We have received the Register of Cornell University for 1902-3. It contains notes on its foundation and endowment, a list of the board of trustees, the departments and faculties, the officers of the University, information on admission and classification, residence and graduation, scholarships and prizes, the graduate department, the academic department, the college of law, the medical college the New York State veterinary college, the college of agriculture, the New York State college of forestry, the college of architecture, the college of civil engineering, the Sibley college, the University library, the Sage chapel and Barnes hall, the Cornell infirmary, a list of fellows and scholars and a catalogue of students. The total number of regular students is 2,068.

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

BY CARL HERING.

## INDUSTRIAL ELECTROCHEMISTRY.

*Production of Zinc.*—Getting zinc from its ores, particularly from poor ores, is a very tempting process for electrochemists, as the field would be a large one, but the difficulties seem to be in proportion, and so far the success does not seem to have

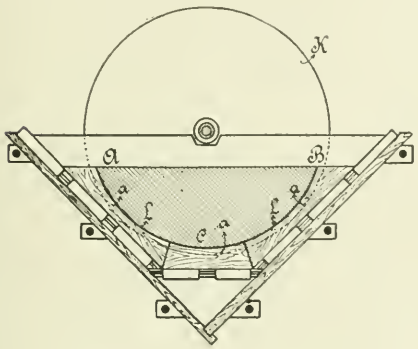


FIG. 1.—HOEPFNER CELL.

been very great. One of the inherent difficulties is that the combination heat of zinc compounds is generally rather high, thus necessitating the expenditure of a relatively high power; and for the same reason other metals are apt to deposit first, thus necessitating a pure solution. The late Hoepfner devised a process which was in use in Fuhrfort, Germany, from 1805 to 1897, but was discontinued, although, it is claimed, this was for personal and not for technical reasons. GUENTHER, in the *Eng. and Min. Jour.*, May 16th, gives a long illustrated description of this process, which is briefly as follows: The raw material was the cinder from zinciferous pyrite, mined in Westphalia, the zinc tenor of this cinder varying from 10 to 10 per cent. The preparatory treatment consisted in grinding the cinder to 1.5 mm size, mixing with 18 to 20 per cent. of common salt, and roasting in a muffle furnace for twenty to twenty-two hours at a temperature of not over 650° C. The charge of the cinder per furnace was 4,500 kg and the coal consumption 900 kg per charge. The charge drawn from the furnace was leached, while still hot, in iron vats with water or dilute liquor from a subsequent stage, affording a solution containing about 10 per cent. of zinc, besides sodium chloride, sodium sulphate, and small quantities of lead, copper, cadmium, arsenic, manganese and thallium. The sodium sulphate was crystallized out as $Na_2SO_4 + 16\ H_2O$ by cooling the solution to —5° C, after which iron and manganese were precipitated by the addition of bleaching powder and marble dust, and finally the electronegative metals by means of zinc dust. A clear solution of the chlorides of zinc and sodium was thus obtained, which on the average assayed 20 per cent. $ZnCl_2$, 22 per cent. NaCl, 0.05 to 0.06 per cent. $H_2SO_4$, and traces of lead, iron and thallium, and after acidification with a small amount of hydrochloric acid, free from arsenic, was ready for the electrolysis. The electrolytic vats were V-shaped tubs; the anode and cathode compartments were separated from each other by means of a diaphragm of nitrated cloth. The arrangement of the vats is shown in the two adjoining figures, of which Fig. 1 is a transverse section of the electrolytic vat through the cathode cell, and Fig. 2 a plan; *a* is the cathode, *b* an iron sleeve to secure it to the shaft *c*, *d* the anode, and *e*, *f*, *g*, *h* the mechanism for revolving the cathodes, while *i* and *k* are conductors for the current. Artificial carbons, hard as glass, were used as anodes, while the

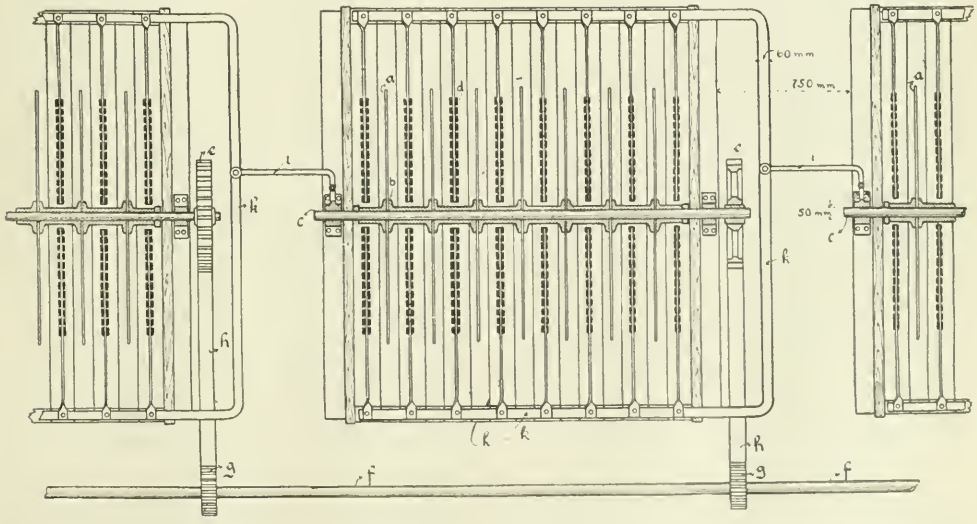



FIG. 2.—ARRANGEMENT OF CELLS IN THE HOEPFNER ZINC PROCESS.

cathodes consisted of discs of zinc or iron, arranged vertically on the horizontal shaft so as to revolve between a pair of adjacent anode cells. Each vat had 8 anode and 7 cathode departments. The electrolyte enters each vat on one of the

horizontal sides, and comes out at the top of the opposite side, so there is only a circulation past the cathodes, but the solution can pass beneath the anode cells; the diaphragms which are closed on top, where they are made air-tight by means of melted pitch, prevent a rapid motion in the anode cells. The solution entering the vats had a tenor of 9.5 to 10 per cent. Zn, and the tenor of Zn in both should not be less than 2 per cent. The acidity to be maintained at 0.08 to 0.12 per cent. HCl, and during the electrolysis acid was added to the extent of 0.03 to 0.05 gram HCl per ampère hour. A good deposit of zinc could not be obtained from neutral or alkaline solutions. The vats were connected in series and a current density of 100 ampères per square meter used, which, the author believes, was less than desirable; the terminal voltage of the bath was 3.3 to 3.6 volts; in regular operation zinc would deposit on the cathodes in dense form, silver white in color, and the current efficiency was 97 per cent. or more of the theoretical. After thirty to thirty-five days, when 800 to 1,000 kg of Zn had been deposited, the cathodes were replaced by a new set. The zinc was then remelted in a reverberatory furnace, losing 1.5 to 2 per cent. in weight, "wherein the consumption of coal was 7 to 8 per cent.;" the final product assayed 99.97 to 99.98 per cent. Zn, 0.01 to 0.02 per cent. Pb, and traces of iron and thallium. The anode cells had an outlet pipe of glass or hard rubber; the chlorine gas liberated by electrolysis was used for making bleaching powder. The author then gives an estimate prepared by him of the cost of plant and operation for producing 650 metric tons of spelter per year, and the corresponding quantity of bleaching powder. This estimate appears to be based on commercial conditions existing in Germany; he reaches the conclusion that the profit in the whole process will be $13,500, as the return on an investment of $162,500 in plant.

*Electrogalvanizing.*—It seems that the replacing of the hot process of galvanizing by the electrolytic process of zinc plating is at last beginning to be appreciated and is finding a field in the ship-building industry, where it is said to be used extensively with excellent results, provided the process is properly carried out. It seems, however, that sometimes the work may have a good appearance, but when tested it is found to be only colored or flashed with zinc, due to a bad connection or the bath being too acid, or the dynamo of too small a capacity for the size of the work under treatment. According to Cowper-Cowles, who has done so much pioneering work in this field, an electrogalvanizing plant, he says, should be so arranged as to be practically automatic in order that it can be placed in the hands of any intelligent workman. This, he claims, is accomplished by doing away with zinc anodes, substituting insoluble lead anodes for them and replenishing the zinc deposited from the electroylte by passing it over filter beds containing zinc powder or dust. A plant of this kind, recently installed in London, is described by him in the London *Elec. Rev.* for April 24th.

*Siloxicon.*—This is the name given to a new compound recently patented by Acheson, as noticed in Electrochemical Industry. It is composed of silicon, carbon and oxygen, and promises to be very valuable in metallurgical apparatus as a refractory material. It seems to contain various oxygen compounds of carbon and silicon, whose formulas vary from $Si_2C_2O$ to $Si_3C_2O$. The former may be considered typical of the new substances and is formed according to the equation:

$$2\ SiO_2 + 5C = Si_2C_2O + 3CO.$$

In the *Eng. and Min. Jour.*, May 16th, Fitzgerald describes this material, as also the furnace for making it. The material is of a gray-green color, has a density of about 2.75, is inoxidigable, infusible, neutral, insoluble in molten metals and unaffected by any acids, with the exception of hydrofluoric, which seems to act on it very gradually. Many experiments have been tried on siloxicon as a refractory material for lining furnaces, crucible manufacture, etc., and as far as these experiments have gone, the substance promises to be a valuable addition to the industrial arts.

*Formation of Insoluble Compounds.*—Isenburg gives a long account of experiments on the formation of insoluble (or difficulty soluble) compounds, especially white lead, by electrolysis with soluble anodes, by the method of Luckow. It is published in the *Zeit. f. Elektrochemie*, April 9th. The principle of this method is to use a mixture of two electrolytes and an anode of the required metal, one electrolyte having an anion the required acid radicle, the other electrolyte being another indifferent salt the acid radicle of which forms with the anode an easily soluble compound. An example of this method, studied by LeBlanc and Birdschedler, is the formation of lead chromate by using lead as anode and a mixture of potassium chromate and potassium chlorate as electrolyte. The authors found that when the concentration of the chromate ions is small, compared with the concentration of the chlorate ions, the formation of lead chromate goes on easily, and the anode remains bright lead. They gave the following explanation of this fact which appears at first sight difficult to understand: if an electrolyte of potassium chromate alone is used, lead chromate is formed immediately on the surface of the lead anode and the anode is thus covered with a firmly-adhering layer of lead chromate; the further formation of lead ions is thus made impossible and peroxide of lead is formed. If, however, a mixture of potassium chromate and chlorate is used with a surplus of the latter, then a layer of lead chlorate (which is soluble) is formed in the neighborhood of the electrode, and the formation of lead chromate occurs at some distance from the electrode, namely, at the points where the layer of lead chlorate is in contact with the potassium chromate; the lead chromate thus formed, cannot adhere to the anode which therefore remains bright, and the process thus goes on without difficulty. The present author has studied the analogous process for making white lead. He experimented with a 1.5 per cent solution of a mixture consisting of varying quantities of $NaClO_3$ and $Na_2CO_3$, and found that in this case also the current efficiency is higher and the lead anode remains in better condition, the greater the amount of $NaClO_3$ compared with that of $Na_2CO_3$. There is no formation of lead carbonate, if only $Na_2CO_3$ without $NaClO_3$ is used as electrolyte. Stirring may in this case have bad effects, as it brings the carbonate ions directly to the anode so that the formation of lead carbonate occurs directly on the surface of the electrode, instead of at some distance from it. In his experiments carbonic acid was supplied in such a way that small bubbles were rising slowly at the anode upwards. The current density was 0.5 ampères per square decimeter. It appears that the supply of carbonic acid must be kept very carefully within certain limits in order to obtain a pure compound $2PbCO_3$, $Pb(OH)_2$.

*Ozone.*—An illustrated article on the preparation of ozone by electricity is begun by Kausch in the *Elektrochem. Zeit.*, for April. The original apparatus of Werner Siemens and the modern arrangements of Siemens and Halske are described.

## THEORETICAL AND EXPERIMENTAL.

*Ions in Solution.*—An article from the president of the Reichsanstant. In the present one, which is published in the *Proc. of the Royal Soc.*, April 7th, abstracted briefly in the London *Elec.*, April 24th, Kohlrausch offers a new and interesting hypothesis of the nature of ionic mobilities, based on the latest determinations. According to this the ion carries with it a mass of adhering solvent, which he calls its "atmosphere." The atmospheres of multivalent or compound ions differ from those of monatomic ions. He thus attempts to reduce the properties of ions in electrolytes to one fundamental element, *i. e.*, their hydration or power of forming an atmosphere. The water atmosphere formed varies according to the nature of the ion, while the mobility of this complex and its temperature coefficient are functions of these atmos-

pheric formations. In general, the existing knowledge about the molecular forces is insufficient to describe this connection more exactly. "But for the case in which the water cell is so thick that the ion exerts no force beyond it, the resistance to motion becomes simply a matter of water friction, which explains the fact that the most sluggish ions have nearly the same temperature coefficients as the viscosity." If the electrolytic resistance is in reality a mechanical friction, it follows that the mobilities of all the ions converge toward zero at about the same temperature, namely 40° below zero.

*Solutions in Amyl Amine.*—An account of an experimental investigation of the electrical conductivity of solutions in amyl amine is given in the *Jour. Phys. Chem.*, April, by KAHLENBERG and RUHOFF. Silver nitrate, cadmium iodide and ferric chloride are soluble in amyl amine, and the resulting solutions are electrolytes, although rather poor ones, compared with aqueous solutions. Some of the interesting results obtained are as follows. The molecular conductivity dwindles to nearly nothing in a silver nitrate solution about $\frac{1}{8^2}$ normal, which is by no means a very high dilution. In the cadmium iodide solution the conductivity is equally low when the solution is as strong as one grammolecule in 5.5 liters, and the ferric chloride solutions when still far from very dilute, also show a low molecular conductivity. This is interesting in studying the role of the solvent in causing electrolytic conduction. In these amyl amine solutions the ability of the solvent to produce with the solute a liquid having electrolytic conductivity is slight. The molecular conductivity of strong solutions of silver nitrate and cadmium iodide, increases as the solutions are diluted, but after passing a certain point, the maximum, the solute and solvent are no longer able to influence each other so as to give increased conductivity, and a further addition of the solvent therefore leads to a lower conductivity. From the point of view of the Nernst-Thomson theory, the conductivity of solutions in amyl amine is relatively high as compared with solutions in chloroform and ether. A comparison of existing data on the conductivities of solutions in solvents in the series in which liquid ammonia is the first member, methyl amine the second, and amyl amine a "higher homologue," would indicate that the conductivity of the solutions diminishes as the solvent occupies a higher position in the series. This behavior is similar to that found in other homologous series of solvents; the series of the primary alcohols, of which water may be considered as the first member, presents a typical example.

*Action of Hydrochloric Acid Solutions in Various Solvents Upon Metals.*—The opinion is often expressed that there cannot be any chemical action except between ions, and that the presence of water or moisture is an essential condition for enabling a chemical action to take place. Kahlenberg, however, has shown that the oleates of copper, nickel and cobalt dissolve in benzine to form non-conducting solutions, and that dry hydrochloric acid gas precipitates instantly the chlorides of these metals. He also found other similar and analagous reactions. In order to further study the action of chemicals upon each other in solutions in which the conduction of electricity is extremely slight, PATTEN has dissolved gaseous hydrochloric acid in various solvents, and brought the resulting solutions into contact with a number of metals and carbonates. In some cases hydrogen or other gas was evolved from the metal, and a chloride of the metal was formed; while in others one metal was attacked and this metal deposited from solution upon a second metal. In still others, no gas appeared and no deposition of metals upon each other was noted, but still some metals were corroded, and some solvents of themselves attack the metals. The arrangement of the apparatus and the results of his experiments are described in detail in the *Jour. Phys. Chem.*, March. It appears that the presence of water is not a necessity in order that chemicals may react upon each other. A chemical system need not conduct electrolytically in order that chemical action may take place. Chemical individuality and chemical affinity are the main factors in chemical reactions, while temperature, pressure, surface conditions, and the masses of the acting substances, also exert great influence upon the nature, direction and extent of the reaction. In general, a chemical reaction goes on in such a way that the potential energy of the system is reduced to a minimum. The impulses which initiate chemical action require further study. The probability is that a vibration of a proper period must be set up in the system before chemical reaction will take place, and on this basis we can understand why certain reactions require a definite temperature; likewise why substances are stable between definite limits of temperature. While the mass of evidence disposes of the idea that chemical reactions go on, even in the most common cases, because of the previous splitting up of the substance into ions, yet it remains to explain the fact that a third substance facilitates chemical action. In many cases the union of reacting substances into a complex compound, and their subsequent splitting off in altered form, is a demonstrated fact. The union of solvent and solute in solution, and the many reactions which take place in solution, fall directly in line with the explanation of the function of a third substance. There is an interesting appendix to this paper, referring to a statement of Remsen that he had been unable to get hydrogen by acting upon dry zinc with hydrogen chloride dissolved in dry benzine. This is in contradiction with Kahlenberg's results. The present author shows that Remsen's failure was due to the fact that moisture was not excluded in his experiments. Kahlenberg's results are confirmed.

*Electrolysis of Water.*—Bigelow recently made a very extended series of experiments on the continual electrolysis of water at voltages below the decomposition value, a subject which has attracted the attention of many. WHITNEY, in a recent article in the *Jour. Phys. Chem.* for March, thinks that a strict application of the Nernst formula for c. m. f. of polarization would explain all the phenomena observed and described by Bigelow without the necessity of introducing any new corpuscular hypothesis. Whenever an electromotive force is applied to a pair of electrodes in an electrolyte, if its value is too small for visible electrolysis, there immediately occurs at least such an amount of real electrolysis as is capable of changing the poles into electrodes whose characteristic c. m. f. is equal and opposite to the impressed c. m. f. The earliest experiments on polarization point to this as a fact. In the case of an aqueous solution, the electrodes at 1 volt impressed c. m. f. are so charged with oxygen and hydrogen that they are to be considered as gas electrodes of low gas concentration or pressure. The gases can escape as bubbles only when the concentration has at least reached that value at which a gas pressure equal to that upon the liquid is reached, *i. e.*, the atmospheric pressure. As the gases, when dissolved in the electrolyte, are capable of depolarizing the electrodes, especially the hydrogen and oxygen electrode, a current at very low voltages seems a necessary result. It should depend largely on diffusion and convection, as the actually studied current evidently does. In the decomposition of water by the current in general, electrical energy and heat are both absorbed, but the quantitative relation between the two varies with the conditions. Moreover, at a given temperature it varies with the pressure, so that at low pressures less electrical energy should be necessary than at high, although the total energy should be the same in all cases. The total energy difference between the water and its gases will be the same at a given temperature for all concentrations because of the constancy of the value of the product of pressure and volume for these gases, but the difference in free energy will depend upon the pressure and volume of the gases, for the greater the volume the less the free energy which they contain. The electrical energy obtainable from these gases under ideal conditions is a measure of the free energy they contain. At great attenuations this would become very small, though the heat of

reaction would be the same as before, conversely, the decomposition of water into these attenuated gases requires the application of but little work. The quantity factor of the electrical energy necessary to decompose the water is the constant of Faraday's law, but the intensity factor by which this must be multiplied to give the energy necessary is the e. m. f. of polarization. This, in accord with the Helmholtz-Nernst conceptions, is a function of the concentration at the active electrodes. Whitney claims that Bigelow's experiments support this view.

*The Disintegration of the Anode.*—In a very long discussion of this subject by Wohlwill, he first treats of the formation of the anode slime in electrolytic refining. This, he says, is mainly due to the non-uniform composition of the anode. Particles of poor conductivity are embedded within those of good conductivity, and when the latter go into solution those of poorer conductivity drop into the slime. The author points out, however, that if an absolutely pure and uniform copper anode is used, in pure sulphuric acid, there is observed the formation of a fine red powder on the anode. He believes that this must be a precipitate from the electrolyte, but as it is formed from the beginning of the electrolysis of sulphuric acid free from copper, the only possible assumption is that this powder is formed by the discharge of freshly-formed copper ions. He assumes that cuprous ions go into solution, which as soon as formed are changed into cupric ions and uncharged metallic copper, the latter appearing in the form of powder on the anode. The author gives an account of a long series of experiments in which he endeavored to find quantitative relations for his theory and discusses the difficulties of these experiments. He gives a long list of facts which support his theory, both of which are given in the *Zeit f. Elektrochemie,* April 23d.

*Electrolytic Oxidation of Aromatic Compounds.*—In the *Zeit. f. Elektrochemie,* April 30th, Sebor gives an account of some experiments in which he investigated the conditions under which aromatic compounds can be oxidized electrolytically. In the special case investigated by him platinum and lead anodes are used, and the latter were found greatly preferable. In order not to get too low a current efficiency, a high current density is to be used, but the current is nevertheless small.

*Unipolar Induction in Electrolytes.*—This improperly-named phenomenon is that which takes place when one tries to send an alternating current through a solution when one electrode is aluminium. The result is that the current can pass in only one direction, and hence, in a sense, will be rectified into a direct current, or more correctly, all that in one direction will be stopped by this so-called aluminium check valve. Isenburg made some experiments recently with direct currents. He electrolysed a 1.5 per cent. solution of a mixture of $Na\ NO_3$ and $Na_2\ CO_3$ with lead electrodes and measured the e. m. f. of the cell as well as that of each electrode against an auxillary cadmium electrode. The e. m. f. of the cathode against the cadmium plate remained constant, while that of the anode increased. The e. m. f. of the cell increased in six hours from 1.6 to 30 volts. On the other hand the e. m. f. of the polarization current, which was also determined, increases from 1 volt to only 4 volts. He concludes that the enormous rise of the e. m. f. of the cell is due to the foundation of a layer on the anode, which is a bad conductor. This is similar to the behavior of an aluminium anode when used as an electrolytic valve. Here there is also a formation of a layer of poor conductivity, and at the same time there is a condenser action. His experiments are described in the *Zeit. f. Elektrochemie,* April 9th.

*The Dissociation Constant and Identity and Purity of Organic Compounds.*—Scudder recently made a long investigation of the reliability of the dissociation constant as a means of determining the identity and purity of organic compounds, from which he concludes that the dissociation constant is a moderately reliable aid to identification, but its use is limited. If, for any compound, the constants found by different observers agree within 10 per cent., the agreement is satisfactory, but the agreement between the values of the constants at different dilutions does not give a satisfactory guide to the purity of the compound that is being measured. This fact lessens the reliability of the constant as a means of identification. For further details see *Jour. Phys. Chem.,* April.

*Chemical Affinity at Very Low Temperatures.*—Moissan and Dewar have made some experiments with the reactions of liquid fluorine at —187° C, which will be found in *Comptes Rendus,* March 30th, or *L'Electrochemie,* April.

## PRIMARY AND SECONDARY BATTERIES.

*Preparation of the Active Material for Lead Storage Batteries.*—There is probably no one who has made more extended researches to try to find binding materials for the active matter in lead accumulators than Leimer (whose name in German, by a curious coincidence, means one who glues or pastes). The first parts of his very long paper have already been noticed in the Synopsis for April. The conclusion is given in the *Centralblatt f. Accum.,* March 15th, where the results obtained with the various preparations of the active mass are given. He divides the various materials, used to make the mass more coherent and durable, into two classes: First, those which of themselves are of a pasting nature, like glue; second, those which produce greater adherence by chemical action. To the first group belong cobbler's wax, amber, collodium, gelatine, sugar, etc. These materials give to the lead oxide a strong mechanical firmness and a high electric resistance of greatly varying value. The principle of the second class is to mix the lead oxides with chemical substances which change a portion of the lead oxides during the pasting and drying process mostly into basic lead compounds, which grow out of the lead oxide particles and thus produce a very firm mechanical connection between the latter. On account of the high percentage of lead contained in them, the resistance of the active mass is relatively very low. The durability of such active masses is also great. To this class belong sulphuric acid, many organic substances, organic and inorganic salts and bases, if free from chlorine. The exceptions are carbon hydrates, oils, etc. There are systems in which the positive active mass is formed with 160 ampère hours per kg, while the change of minium into peroxide theoretically requires 147 ampère hours, and it is possible with a low watt load to get up to 105 ampère hours per kg of positive active mass, presumably referring to a subsequent discharge of the finished plates, but this was possible only when the best materials of the above second class were used. With materials of this class it is necessary to take care not to use anything which would have a destroying effect on the lead support. Moreover care should be taken in mixing two such materials together. He mentions instances in which two materials, each of which gave good results when used alone, gave bad results when mixed together. The author, in conclusion, mentions the following method of making an active mass: It consists in bringing the lead oxides mixed with pure water and after having been pasted into the frames of grids, into an air-tight closed drying oven, through which the materials which should give greater coherence and durability were passed in vaporized form. Since 1898 batteries made by this method have been in continuous operation for benzine automobiles, and have proved very successful. When he used pyridine for this purpose, which smells badly, then the vapor which left the drying oven had a pleasant odor like amyl acetate. It was surely no longer pyridine, hence had acted chemically on the plates. The same method may be successfully used for hardening old plates which have become soft.

*Electric Lighting of Railway Cars.*—Goetze continues his illustrated article on the various systems used for the electric

lighting of railway cars with the aid of accumulators in the *Centralblatt f. Accum.*, April 1st and 15th, May 1st.

## GENERAL AND MISCELLANEOUS

*Acetylene Central Stations.*—The first two acetylene central stations in Germany were opened in 1897 and proved so successful that many more were erected in 1899 and 1900, so that at the beginning of 1900 there were 25 stations in operation, after which the progress was slower. The reason for the latter seems to have been mainly that the first installations erected were more or less experimental, and that their cost and the repairs or extensions which later become necessary required so much capital that no dividends were earned. VOGEL, in a recent lecture before the German Acetylene Society, believes that now, after experience has been gained, the commercial prospects are much more promising, and he recommends, the erection of an acetylene central station for any town having up to about 8,000 or 10,000 inhabitants. A condition which must be fulfilled for commercial success is that the houses must not be scattered too much. There should be at least about 150 lights for each kilometer of street pipe, if the gas is to be sold at 45 cents per cubic meter, the present price of calcium carbide in Germany being given as $7 per 100 kg. He claims that the operation of an acetylene central station is much simpler than that of any other gas works and that no other gas is hygienically as safe. The fear of the danger of explosions has been greatly exaggerated. The main point is that the first cost of the plant is very low. For a town of 4,000 or 5,000 inhabitants with a pipe network of 8 km length, with 80 to 100 street lamps and a total of 1,500 connected lights, and a gas reservoir of 100 cubic meter capacity, an acetylene central station can be built for $17,500, while another gas plant of the same size would cost at least $40,000, and an electric plant $50,000. In conclusion the author reproduces reports of physicians who state that for the eyes acetylene light is the best for reading. His lecture is published in the *Zeit. f. Calciumcarbid Fab.*, April 30.

An illustrated description of the acetylene central station in Doese, Germany, is given in the same journal for May 8th.

An article by KEPPELER on impurities in commercial acetylene and on its purification is given in the same journal for April 9th and May 1st.

*Decay of Metals.*—MILTON and LARKE have made some experiments to determine the galvanic action between copper, iron, brass, Muntz metal, etc., when in contact with sea water. Other experiments showed that weak applied currents, when long continued, had a decided corrosive action upon copper and its alloys when immersed in sea water, the amount of corrosion with the same current being greatest in those alloys containing the highest proportion of copper. With a current of 0.001 ampères acting on an immersed area of 30 sq cm in the case of Muntz metal, the wasting produced was confined to the dezincification of the constituent poorest in copper, but the same current, acting upon 60 sq cm of ordinary brass condenser tubes, gave rise to a fairly uniform corrosion, both the copper and the zinc of the alloy being dissolved. It appears that decay was more frequent in metals which had a duplex or more complex structure than in those which were comparatively homogeneous, and was due to a slower or less energetic action than that causing corrosion. Moreover, it involved an action which removed only part of the constituents of the metal, whereas corrosion might result from chemical action alone, or from chemical and electrolytic action combined. Pitting, or intense local corrosion, was probably often due to local segregation of impurities of the metal, but it might also in some cases be due to local irregularities of surface or structure producing local irregularities in the distribution of the galvanic currents. In the case of brass exposed to sea water, tin was distinctly preservative, while lead and iron were both injurious, rendering the brass more readily corrodible. The percentage of the latter elements should, therefore, be kept as low as possible in all metal intended for purposes where contact with sea water was inevitable. The experiments with an applied current show that electrolytic action alone, even where exceedingly minute currents were in question, might result in very severe corrosion or decay. Every effort, therefore, should be made to prevent such action by careful insulation of all electric cables. Where galvanic action was inevitable through the proximity of different metals exposed to the same electrolyte, the resulting currents should be "neutralized" (sic) by the application of zinc plates in the circuit, so arranged that they would be negative to both of the other metals. Their experiments were described in a paper read before the (Brit.) Institution of Civil Engineers, an abstract of which is published in the London *Elec.*, April 24th.

*Separation of Metals by Electrostatic Means.*—The use of electrostatic forces to separate metals from their ores, or from each other, seems to be meeting with some favor. A method of this kind is in commercial use in Denver. NEGRESNO has made some experiments in this direction which he described before the French Academy, an account of which is published in *Comptes Rendus*, April 20th, an abstract of which appears in the London *Elec.*, May 8th. He cut a central disc out of a horizontal metallic plate and connected it to the positive pole of a Wimshurst machine, the remaining part of the plate, which is separated slightly from the disc, being connected to the negative pole. He then dusts a mixture of sand and finely-divided metal upon the plate and disc, and finds that the sand is deposited upon the disc and the inner rim of the plate, while the metal is deposited near the outer rim of the plate. In another form of the experiment the plate is left whole, and a separate disc is attached to the positive pole and brought near the plate from above. When a mixture as before is dusted upon the plate, the metal is driven to its outer edge, and many of its particles fly up and deposit themselves on the upper surface of the disc. The experiment succeeds very well with a mixture of sand, copper or bronze, almost the whole of the metal being transferred to the disc. The particles then transferred follow very closely the lines of force as traced out in a condenser. The method may be useful in the separation of metals from their ores, and also in the separation of two mixed metals; thus in a mixture of powdered brass and copper, the brass is repelled and deposited on the upper disc.

*Electric Power in Mines.*—The *Zeit. f. Elektrochemie*, April 16th, has an article by SCHNEIDER on electric installations of various mines in Germany. Some researches on the utilization of blast furnace gases in gas engines are referred to. The engines have recently been greatly improved, and the difficulties due to the lack of uniform composition of the gases, their impurities and their relatively small caloric value, have been partly overcome. He believes that there is no doubt a great future for the blast furnace gas engine. Many coal mines have a gas which is even more suitable for gas engines. The coke ovens give an average of about 25 per cent. greater gas volume than that required for heating the furnaces. The caloric value of the gases averages 4,000 calories. With these numbers as a basis, a battery of 50 furnaces would give a surplus of 520 cubic meters of gas per hour, which when burned under boilers gives about 300 h.p., but when used in gas engines about 655 h.p. In the coal mine region of Westphalia about 100,000 h.p. are thus available. Several such plants are now installed in Germany.

*Measuring the Temperature of Furnace Gases*—The Lond *Elec.*, March 27th, notices a paper by PRICE, read before the Manchester section of the (Brit.) Inst. Elec. Eng., on the use of the potentiometer in the measurement of temperatures of flue and furnace gases. With a reflecting galvanometer, used in conjunction with a potentiometer and a thermopile, the recalescent points of steel and copper were shown. The author's thermopile was composed of platinum and an alloy of platinum and iridium, and, with temperatures of about 2,000°

F. readings are said to be obtained with an accuracy of 10 degrees. The chief use to which the apparatus has been put was that of testing samples of magnet steel. Pooley remarked that he thought the method of taking furnace temperatures by means of the resistance of a platinum coil inserted in the furnace was the one most generally used, and was quite simple, as the resistance of platinum varies very regularly with different temperatures.

*Russia.* *Cassier's Mag.* for April contains an illustrated article by Heenan on electrical developments in Russia. The progress of the electrochemical and electrometallurgical industries is interwoven with the utilization of hydraulic power for current generation. There are several electrolytic copper refineries, a calcium carbide plant and a large caustic soda plant. Electric welding is in use in a number of works. Cables and storage batteries are made in some Russian factories.

*Hydraulic Power-Station Statistics for France.*—There is a long table, by Cornet, in *L'Ind. Elec.*, April 10th, giving some statistical data on hydraulic stations in France. It states what they manufacture, where they are located, the height of the fall and the hydraulic power "en poncelets" (presumably in horse-power). There are three aluminium plants, power 16,802; five electrometallurgical plants, power 15,166; two potassium chlorate plants, power 6,750; fifteen calcium carbide plants, power 72,063; one sodium and chlorine plant, power 10,125; twenty-one stations for distributing electric power and light, power 28,667; twenty-two printing and paper mills, power 9,551; four textile mills, power 695; one saw mill, power 60; six cement factories, power 1,913; two potteries, power 151.

*Electrochemistry in the United States.*—Professor Haber was sent to this country last year by the German Bunsen Society to report on the development of the electrochemical industry in this country. This report has now appeared in the form of a long lecture, giving a summary of the methods of teaching electrochemistry in America universities, and of the industrial development of electrochemistry in the United States. It is published in the *Zeit. f. Elektrochemie*, April 16th and 30th, and will be found abstracted at considerable length in the present issue of Electrochemical Industry.

## Book Reviews.

A Text-Book of Inorganic Chemistry. By Dr. A. F. Holleman. Translated by H. C. Cooper, Ph.D. New York: John Wiley & Sons. Price, $2.50.

We have here a text-book of inorganic chemistry, which has been written for a purpose. The author says in the preface that when the original Dutch edition appeared no text-book of inorganic chemistry existed in which the modern views introduced by van't Hoff, Ostwald, Arrhenius and others were sufficiently regarded, and that he therefore wrote it as a guide for his lectures.

His book is, however, not a text-book of physical chemistry (of which we have several of merit in the English language), but a text-book of inorganic chemistry, in which, with a moderate amount of descriptive matter on the elements and their compounds, we have a continuous effort to explain chemical phenomena as observed in the lecture room, the laboratory and in manufacturing practice by the newer physical theories and laws. Many of these explanations are extensively ingenious, and at the same time satisfying; others are at least plausible. Let us take, for example, the discussion as to the character of hydrochloric acid, on page 39. The author shows that hydrogen chloride does not follow the law of Henry in its behavior towards water; that its solubility is not at all proportional to its pressure, and that the chemical properties are found to be quite different when it is in a perfectly dry condition, as gas or condensed to a liquid, and when it is dissolved in water. This difference he shows to be clearly due to dissociation of the hydrogen chloride in solution. The whole theory of dissociation is clearly stated on pages 76 to 81, and shown to be a sequence of the law of *mass action*, and electrolytic decomposition is simply shown to be a grouping together at the electrodes of the ions already separated by the process of solution. This leads the author, on page 100, to give a new definition of acids and bases more in accord with these views than the familiar one of most text-books. Acids he defines as "those substances which give H ions in aqueous solution; bases, under the same conditions, give OH ions."

The theory of osmotic pressure and its analogy to the laws of Boyle and Gay Lussac for gases is also very clearly explained on pages 56 and 57, and the application of this theory in measuring the depression of the freezing point and the elevation of the boiling point of liquids and the value of this in determining molecular weights is then shown, and the methods explained and apparatus described on pages 64 to 67.

Most interesting is the application of the ionic theory and the deductions therefrom to explain the phenomena of percipitation under varying circumstances, as, for instance, why some elements are precipitated from acid solution by hydrogen sulphide and others not, as given on pages 115 to 118; and, again, the effects of hydrolytic dissociation on precipitation phenomena in general, as stated on pages 328 and 329.

The theory of ammonium salts and the readiness with which some of them yield ammonia is also well stated and explanations given on page 315. The theory of electrolytic dissociation is very ingraciously brought in to explain the basic or acid reaction in the case of some salts called neutral from the point of view of their chemical constitution, and illustrative cases given on page 328.

Among the practical applications of some of these physicochemical theories we have, on page 391, the account of the different behavior of tinned sheet iron and galvanized iron. Tinned iron, if scratched at any point, rusts faster than iron alone, while galvanized or zinc-plated iron does not rust even where the plating is worn off. This, the author explains, is due to the fact that in the presence of moisture, as an electrolyte, the metal with the greatest solution tension goes into solution and the steel remains intact.

Of course, the periodic system of the elements is given a very full and thorough presentation, and the arrangement of the book is that indicated by this method of grouping. The value of the periodic system in indicating the relative position and relationship of newly-discovered elements is very well explained. Lothar Meyer's well-known curve, in which the elements are plotted, follows in the rear of the book on a plate.

The book is, throughout, very suggestive to a thinking student of chemistry, and will undoubtedly point out the explantion of many apparently little-understood phenomena, and perhaps contradictory phenomena. It is, in general, free from errors. One may be pointed out, however—at the top of page 56, where the formula of white lead is given as $PbSO_4$, instead of the basic carbonate.

We feel that the American translator has performed a useful service in bringing out this American edition, and making the book more widely known.

The Mineral Industry. Founded by the late Richard P. Rothwell, edited by Joseph Struthers, Ph. D. Vol. X for the year 1901. New York: *Engineering and Mining Journal*. Price, $5.

Jahrbuch der Elektrochemie. Founded by Prof. W. Nernst and Prof. W. Borchers. Vol. VIII: progress in 1901. Edited by Dr. H. Danneel. Halle: Wilhelm Knapp. Price, $8.

Kalender fur Elektrochemiker for the year 1903. Edited by Dr. A. Neuburger. Berlin: M. Krayn. Price, $1.35.

As these are three annual publications of interest and importance to electrochemists, they may be reviewed together.

*Mineral Industry*, of which we have the tenth volume, referring to the progress made during the year 1901, is so well

known and the completeness and reliability of its statistical data are so fully recognized by everybody interested in the mineral and metallurgical industries that it would be superfluous to dwell on this at length. We may simply say that under its new editor, Dr J. Struthers, the high standard set by the late R. P. Rothwell has been fully maintained. Articles of an electrochemical nature have been contributed to this volume by J. B. C. Kershaw, Titus Ulke and R. L. Whitehead. As with the former volumes, part of this volume was published before in articles appearing in the *Engineering and Mining Journal*. When a new volume of *Mineral Industry* appears most of the information contained in it is somewhat old, but this is an inherent and unavoidable disadvantage of every annual publication. The ten volumes of *Mineral Industry* form the most complete review of the mineral industries in the last ten years.

A relation similar to that between *Mineral Industry* and the *Engineering and Mining Journal* exists between the *Jahrbuch der Elektrochemie* and the *Zeitschrift für Elektrochemie*. The German year book was founded in 1895 by Dr. W. Nernst and Dr. W. Borchers, who at that time were the editors of the *Zeitschrift*. The greatest part of the first volume was written by Nernst and Borchers, but in the following years a greater staff of contributors was won, and Nernst and Borchers acted more and more as editors only. This they continued to do up to the seventh volume. The eighth volume, referring to the progress in electrochemistry during 1901, has been edited by Dr. H. Danneel and the following gentlemen acted as reviewers: Dr. H. Danneel for general scientific electrochemistry, conductivity of solutions, theory of galvanic cells, polarization and electrolysis, radiant and chemical energy; Dr. M. Mugdan, for storage batteries; Dr. P. Askenasy, for industrial progress in inorganic electrochemistry (except metals); F. von Kuegelgen, for industrial electrometallurgy; Dr. K. Elbs, for industrial progress in organic electrochemistry; Dr. W. Borchers, for apparatus for electrochemical practice. There is also a chapter on Becquerel rays by Dr. E. Harms.

The general policy of the *Jahrbuch* has remained the same under the new editor who has fulfilled his duty with remarkable skill. The size of the book has increased again. It has now 725 pages, of which 373 refer to theoretical electrochemistry, and the balance to industrial electrochemistry. The eight volumes of the *Jahrbuch* are certainly the most complete, although somewhat unwieldy, record of the progress in theoretical and industrial electrochemistry since 1894. The reviewers have endeavored not to give simply a record of what has been done or what is claimed to have been done, but they have added critical notes. This is to be recommended as far as it goes, although in industrial electrochemistry practice alone has the last word, and in theory it is not sufficient to make an ironical remark in order to kill an opponent.

*Neuburger's Kalender für Elektrochemiker* was first published in 1896, and was evidently written to give to electrochemists a pocket book of the same nature as the German electrical engineers have in Uppenborn's well known Kalender. To keep such a calender up to date it must be carefully reviewed and overhauled every year. In this respect the last edition of Neuburger's *Kalender* shows a marked improvement over the former editions in which the information given had become quite stale. We hope the editor will continue to work in the same direction in future issues. To make the information given in such a small pocket-book complete, concise and up to date the continual work of years is required. The *Kalender* contains many very useful tables on subjects of electrical and mechanical engineering, chemistry, physics and electrochemistry. The part dealing with electrochemistry proper comprises 300 pages, the contents of which are as follows: Fundamental laws, table of electrochemical equivalents, tables of transport numbers and ionic mobilities, tables of conductivity of dissolved and fused electrolytes, polarization, single potentials of electrodes, tables of decomposition voltages, description of galvanic cells and batteries with rules for manufacturing, installing and maintaining them, electrolytic analysis, tables of formation tents, some notes on industrial electrochemical processes, and prescriptions for electroplating.

## *Correspondence.*

### COST OF ELECTRICAL STEEL PROCESS.

To the Editor of ELECTROCHEMICAL INDUSTRY.

SIR:—I had hoped that some one of your readers would have criticised the figures given in your issue of March, purporting to be the cost of producing steel ingots at the Canonica Works, in Italy, using the Stassano process.

Not that I would for the moment doubt the accuracy of Dr. Goldschmidt's statement; he like "Cæsar's wife" is above suspicion. The figures given, therefore, exactly represent the conditions, as found by him, existing at the time of his visit.

I had hoped, however, that some one of your readers would have pointed out that while the figures represent the working of the process, under the handicapping conditions existing at Canonica, which conditions were no doubt responsible for the stoppage of the works, yet they would not fairly represent the cost of the process under such conditions as are known to exist on this continent.

I am not conversant with kilograms and lires. In my translation, therefore, I may have made some mistakes, but it may be of interest to some to know in dollars and cents the costs found existing by Dr. Goldschmidt at Canonica, and to have these costs compared with the costs which might be expected to obtain at certain locations on this continent.

| | At Canonica | In America |
|---|---|---|
| 3,540 pounds, or say 1⅝ tons of iron ore costing | $4.80 | $1.75 |
| Pulverization of same | .90 | * |
| 480 pounds, or say 1-5 ton of flux | .20 | .12 |
| 550 pounds, or say ¼ ton of coke | 2.25 | 1.50 |
| Pulverization of same | .10 | * |
| 418 pounds, or a little over 1-6 ton addition | 2.66 | 2.66 |
| For making the mixtures | 1.35 | * |
| Wear of electrodes | .72 | .72 |
| Maintenance of furnaces | 2.40 | * |
| Wages | 1.20 | * |
| Utensils | .60 | * |
| Electric power | 4.56 | 2.23 |
| Incidental costs | .60 | * |
| Labor | | 2.50 |
| Repairs, renewals, utensils and sundries | | 2.00 |
| Totals | $22.40 | $13.48 |
| Less volatile and combustible gases obtained | 3.60 | 3.00 |
| | $18.80 | $9.88 |

It will be noted that at Canonica none of the raw materials are cheap, nor is the power, while the wages and repairs, etc., are extravagantly high—caused doubtless by local conditions—such as distance of works from the railroads, size of the plant and variable water supply; the consuming market was also very far away, labor costing $3.61; power, $4.50, repairs, etc., $3.00, again 1 $2.50, $2.23 and $2.

LOUIS SIMPSON.

OTTAWA, CANADA.

### ELECTRIC AUTOMOBILE CHARGING OUTFITS.

While the problem of developing a light storage battery is the most important one for electric automobile people, the question of an inexpensive and thoroughly reliable charging outfit is also a vital one. The efficiency of the electric automobile mainly depends upon the performance and maintenance of its

*This item could probably be largely reduced.

**These gases could be used for the conversion of the iron into steel—so far as they would go.

battery, and for its proper care it is necessary that the charging station shall, in its turn, satisfactorily meet all the practical requirements of every-day service, including use by those unfamiliar with storage-battery charging and limited opportunities for attention thereto. In the following we give a description of a charging outfit of the Westinghouse Electric and Mfg. Co.:

Charging may be derived from any one of three sources—direct current, alternating current or independent power. Combinations and variations admit of 168 different styles of charging outfits, a sufficient variety to meet any and all of the peculiar conditions or demands of either the private or public charging stations. With these combinations one, two, four, twelve or more automobiles can be charged at once. The outfits for charging one or two machines are intended for private use; that with a capacity of four is suitable for clubs, country houses or small stables, while the standard twelve service is applicable for use by public garages, express and cab companies, or other establishments having a number of vehicles.

One of the chief advantages of the garage installation shown in Fig. 1, the only one having this valuable feature, is that all controls are at one point, with minimum apparatus, instead of, as in the former practice, having them individualized and spread over considerable space, involving double the trouble and expense. There is also a saving in that, instead of being compelled to use 12 voltmeters and 12 ammeters, one of each is sufficient.

Another important item is that the charging may be in serial or simultaneous. The cut shows one of these garage switchboards with the series rheostats installed below it for controlling the charging rates of the various batteries. In this particular case rheostats are provided for eight vehicles, the

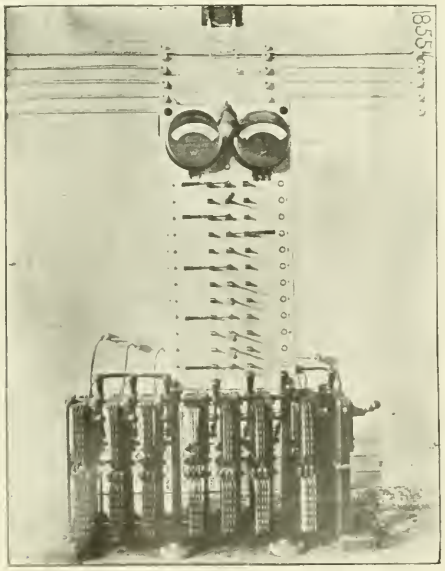


FIG. 1.—CHARGING OUTFIT FOR AUTOMOBILES.

greater capacity being obtained at any time by adding the requisite number of rheostats.

Each switch on the board is numbered to correspond with the number of its rheostat and charging stand. The throwing of a switch to the left places a battery in "charge;" reversing to the right connects the ammeter so that the current may be read. The voltmeter will indicate for the whole main line, or by pressing the push button corresponding to any switch the voltage reading of its stand can be taken. A separate push button gives the voltage reading on the line beyond the rheostats. Opposite each switch is a numbered hook, upon which the charging record of the battery may be kept.

In connection with this central switchboard automatic circuit breakers and fuse blocks are to be used at each charging stand. These switchboards may be connected with any 125-volt, direct-current line, whether from central stations, motor-generator set or independent circuit.

For the one or two vehicles of the private owner, or the small garage designed for four machines, the panels are as shown in Fig. 2, with the necessary modifications in each case, and are adapted for direct-current voltage of 110 to 125. For single charging, the automatic circuit breaker is mounted directly upon the panel, with the meters and fused switch. Where two or more automobiles are to be charged, the circuit breakers are displaced by switches, and the overvoltage circuit

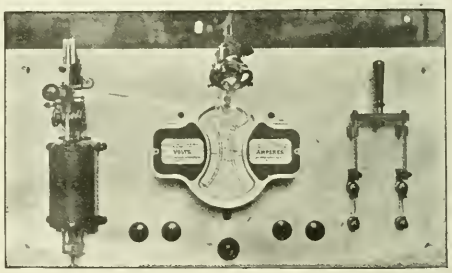



FIG. 2.—CHARGING OUTFIT FOR AUTOMOBILES.

breaker and fuse blocks are located at the carriage-charging stands.

The details of the outfits are of standard Westinghouse make, and are as follows: The panels are of white Italian marble or marbelized slate. The meters, which, for private use, may be a combined voltmeter and ammeter, are provided with sub-scales and convenient terminals for reading voltages of individual cells, with volt scale from 0 to 150, sub-scales 0 to 3 and ampère scales 0 to 100. The switches are of standard Westinghouse type D, of the normal capacity of 50 ampères for each charging circuit, the line switches being fused. The circuit breakers, under normal circumstances, automatically cut out the battery when the charge is completed, and in all cases protect the battery from any overcharge danger or damage, enabling the owner or attendant to set the charge and pay no more attention to it until the machine is again wanted for use without loss or damage of any kind. The motor-starter rheostats, employed in starting the direct-current motors, are mounted on the back of the panels, with handle projecting through, the same as with the generator field rheostats. Where a generator is employed, the latter are used for the regulation of the battery charging of one carriage, without requiring the additional series rheostats of the grid or imbedded type. Where the series rheostats are needed, they are made in one of three types—grid, embedded or combined. In the first form they are mounted on the floor, directly below the switchboard, the grids being of cast iron, set in the open air, thoroughly ventilated, and, while they are normally made to carry 60 ampères each, they can be immensely overloaded without injury, surviving unhurt where other types burn out. This is an important point, since it obviates all danger of battery injury by the burning out of the rheostats, a danger that has been, and in some types still is, found only too frequently. The embedded type of rheostat is in two styles, designed for use with either 10 to 14 or 20 to 24 cells. When charged from a 125-volt line, each will carry continuously 30 ampères, and may be mounted with several of the same type or with the grid type.

One of the greatest advantages of the Westinghouse outfits is that they have no loose wires, thus doing away with all danger from fire. If, from ignorance or carelessness, a mistake is made by the operator, the fuses supply the deficiency by cutting out the current, obviating any injury to the batteries or switchboard. There is nothing complicated about them; nothing requiring technical training or skill; nothing that any man of ordinary mental capabilities cannot master in five minutes. They occupy but little space, the panels for private use being only 14 x 28 x 1¼ inches thick, and those for public garages 22 x 48 x 1¼ inches.

The direct or alternating-current motor generators furnished by the Westinghouse Electric and Mfg. Co. are of standard type, and adapted to the panel used, transforming high-voltage direct current to the proper voltage, or changing alternating current to the desired voltage, direct current for charging. These present an advantage in that, being standard, they are always a marketable commodity.

In cases where the owner prefers his own isolated plant of gas or other power for driving a generator, accessory apparatus to meet the requirements has been added to the outfits.

## THE ELECTROLYTE FOR STORAGE BATTERIES.

We have received from the Franklin H. Kalbfleisch Co., of New York City, a pamphlet, containing an article by Thos. J. Fay, on "Electric Storage Batteries and Electrolyte." It gives valuable information for practical men who have to do with storage batteries, especially for automobile purposes.

The theoretical remarks on page 10 are not up to date and, in view of the extended investigations of Dolezalek, it is not correct to say that the chemistry of the storage battery is by no means understood. But the author evidently does not want to write a theoretical paper, but wants to give practical rules for practical men, and in this purpose he is very successful. In the following we give some abstracts from the pamphlet:

For automobile practice the author gives the following directions for charging a battery: to charge a battery in three hours: first hour, 50 per cent.; second hour, 30 per cent.; third hour, 20 per cent.; to charge a battery in four hours: first hour, 40 per cent.; second hour, 30 per cent.; third hour, 20 per cent.; fourth hour, 10 per cent.; to charge batteries in five hours: first hour, 30 per cent.; second hour, 25 per cent.; third hour, 20 per cent.; fourth hour, 15 per cent.; fifth hour, 10 per cent. In cold weather, the three-hour charge is best, in hot weather the five-hour charge is necessary, but, under normal conditions of temperature, the four-hour charge produces the most satisfactory results.

It is undoubtedly a fact that charging at constant wattage is superior to all other means, but to do so requires that an automatic rheostat be devised; the resistance in circuit to be controlled by two magnets or solenoids in opposition, one of which energized by the charging current and the other by the battery e. m. f. Such a charging equipment is as yet not to be had, but the time is not far distant when manufacturers will see their way clear to devise the constant wattage automatic charging set, for vehicle work, at any rate.

When the batteries are fully charged, the operation of charging should be immediately stopped. The features which indicate that the charge is complete, are enumerated. For battery tests it is recommended to take readings of the single potentials of the two plates by means of an auxiliary cadmium electrode.

The author then deals at length with the problem of the electrolyte. Its strength or density is of great importance, and as it is measured by means of hydrometers, formulas are given which represent the relation between the specific gravity and the various hydrometer scales in use. He points out that the specific gravity of the acid in a storage battery should be between 1.200 and 1.300; to go above 1.300 specific gravity is to risk destroying the plates. The electrolyte should be purchased ready for use, but if it must be mixed on the premises, proceed as follows:

To dilute sulphuric acid—

(*a*) Provide a lead lined tank of suitable size.

(*b*) Wash the tank before use with distilled water.

(*c*) Fill the tank three-quarters full with distilled water.

(*d*) Stir in slowly, pure, concentrated sulphuric acid.

(*e*) When the hydrometer shows that the specific gravity of the mixture is 1.175, discontinue the operation until the electrolyte cools off (it heats in mixing). Then take the specific gravity again. It will then be about 1.200. If, however, a 1.250 specific gravity electrolyte is wanted, raise the gravity of the hot mixture to 1.225, instead of 1.175. If the gravity is not exactly right, adjust it to a nicety when cold, by adding concentrated sulphuric acid to strengthen, and distilled water to weaken.

(*f*) Do not use earthenware, iron or any other ware for mixing the electrolyte, excepting lead-lined tanks, glass or glazed porcelain, but porcelain-lined iron pots will not be a good substitute.

(*g*) When the electrolyte is mixed, put it into carboys, with stopper to keep it pure, until the time comes to use it.

The author emphasizes the enormous importance of absolute purity. He urges that tests for impurities should regularly be made, and gives clear directions how to make simple tests for undesirable ingredients, such as chlorine, iron, copper, mercury and nitrates. Distilled water should always be used, not water from the city mains. He sums up his recommendations as follows:

(*a*) Test the battery when first received for impurities. If the battery comes "knocked down" or "dry," test the plates.

(*b*) Test every carboy of electrolyte received before any of it is used, and, above all, do not purchase electrolyte made from iron pyrites. The only suitable electrolyte is made from sulphur for the acid, and distilled water for diluting.

(*c*) Do not have concentrated sulphuric acid around, as some careless person may put it into the battery, either to bring up the strength of the electrolyte or by mistake.

(*d*) Use only distilled water from carboys, not from barrels, and test every carboy of water received before using.

(*e*) Keep the electrolyte up to strength in the batteries by the following process:

1. Add distilled water to reduce the strength.

2. Add 1.400 specific gravity electrolyte to increase the strength.

3. Test for acid strength always with a fully-charged battery.

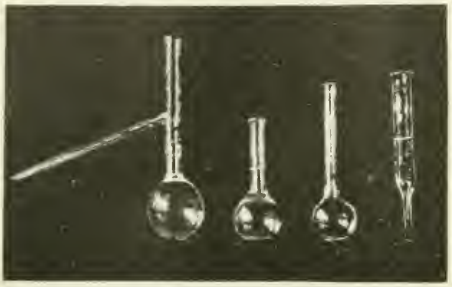
(*f*) Temperature has a marked effect on battery output and acid strength, hence observe the temperature at which all equalizing of electrolyte is done, and either compensate for temperature or wait until the temperature is at some predetermined point, say 60° F.

The pamphlet is concluded by brief, illustrated descriptions of the Gould, Manchester-Chloride, Willard, Porter and Sperry batteries.

The Franklin H. Kalbfleisch Co., who have published this, and other pamphlets on storage batteries, realized the necessity of having electrolyte free from impurities, and were the original manufacturers of pure electrolyte. Their electrolyte is guaranteed to be made from Sicily brimstone, sulphuric acid only, and to conform in all respects with the requirements for storage batteries, of all makes, either for central station work, electric vehicles, or any other uses to which storage batteries are put. They are also large manufacturers of distilled water, to be used in diluting, and make a specialty of these articles, as well as standard battery solutions and chromate salts. They will be glad to send a copy of the Fay pamphlet on request, and also send in addition, any future works which they may issue on the subject.

## CHEMICAL APPARATUS MADE FROM QUARTZ.

Among the chemical apparatus exhibited by Messrs. Eimer & Amend, of New York City, during the recent convention of the American Electrochemical Society, there were crucibles, tubes and flasks blown and drawn of fused quartz. The adjoining illustration represents them in about one-fifth natural size. The credit for this latest achievement in laboratory utensils is due to the firm of Heraeus, in Hanau, Germany. The quartz is not fused by means of the electric arc, but by the oxy-hydrogen flame.



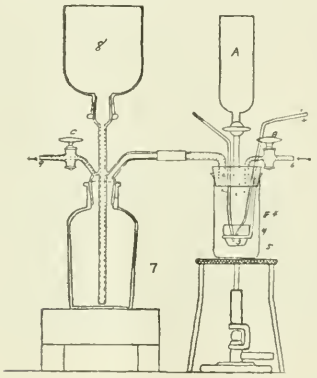
APPARATUS MADE OF QUARTZ.

Sudden, very large temperature variations have no effect whatever on the quartz apparatus. While it is still pretty expensive, it is cheaper than platinum for which it is intended as a substitution in various cases.

## CARBON DETERMINATION APPARATUS.

Among the new apparatus exhibited by Messrs. Eimer & Amend, of New York City, during the recent convention of the American Electrochemical Society, there was a very interesting apparatus, designed by George O. Seward, the managing chemist of the Wilson Aluminium Co., for determining carbon, especially of the electric furnace products, like in ferro-chrome, etc.

The previous best method of determining the carbon in ferro-chrome and like materials which cannot be decomposed by any solution, necessitated the use of a combustion furnace consequent oxidation of the metal and the carbon in the metal is complete in less than sixty seconds.




SEWARD CARBON DETERMINATION APPARATUS.

The adjoining diagram shows the construction of the apparatus which is operated as follows: A is filled with cold, distilled water, and the lower bottle at the left hand with concentrated sulphuric acid to the level indicated (it acts as a safety device to take care of the difference of pressure in the beaker at the right hand).

A 20 cc nickel crucible is then filled with 1 gram of the metal to be analyzed, intimately mixed with about 10 grams of sodium peroxide. The apparatus is then set up as shown in the figure, and purified air is passed through the train for fifteen minutes to expel any $CO_2$ which might be in the train. Two wires, the ends of which reach into the crucible, as shown in the figure, are now connected with a source of electric current, not more than 3 ampères being necessary or desirable at 110 volts.

The two stop cocks, B and C, shown in the figure are closed and the mixture in the crucible is fused by means of the small arc formed between the ends of the two wires in the crucible. The arc is started by touching the two ends and then separating them; after the fusion is started by this means, it will continue through the mass, if the proportions of the metal and peroxide were correct.

The pressure caused by the oxidation of the metal in the crucible will force the acid in the lower bottle at the left side up into chamber S. A weighed KOH bulb is now connected in the train by means of the stock cock C and by opening the latter carefully the passing of the gases through the KOH bulb is commenced, to be continued until the end of the analysis.

When the fused mass in the crucible has cooled sufficiently, water is let into the fused mass and the beaker is filled nearly to the top of the crucible. The remainder of the water in A is then siphoned off and A is filled with a cold mixture of one part of water to one part of sulphuric acid. This is let into the beaker until the solution is strongly acid. The solution is then boiled for ten minutes to expel the $CO_2$, which may be left in the acid solution.

The stop cock at the right hand is then opened and air is passed through the train for fifteen minutes, when the KOH bulb is detached and weighed, the gain in weight being the $CO_2$. As the sodium peroxide on the market at present is not entirely free from carbonates, it is necessary to make a blank determination on each lot of peroxide to determine the amount of carbonates in the same.

The principal claims made for the apparatus are that the apparatus contains no platinum and is therefore very cheap; the operation of analysis is much shorter than by any other method and quite as exact; no hydrocarbons are formed in the combination, which is a decided advantage; the apparatus is very easy to manipulate and duplicate determinations can be carried on at the same time readily; no oxygen gas is used; the fusion and consequent oxidation of the metal and the carbon in the metal is complete in less than sixty seconds.

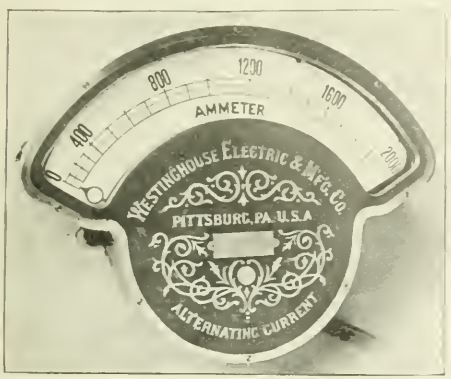
## ALTERNATING CURRENT LONG SCALE VOLTMETER AND AMMETER.

The accompanying cut is an illustration of an improved form of voltmeter and ammeter. These are induction instruments, and in principle of operation are closely allied to the integrating wattmeter made by the same company, the Westinghouse Electric and Mfg. Co.

The scales begin at zero, and the divisions are absolutely proportioned and uniform above 20 per cent. of the full capacity, with a length and openness obtained in no other type, allowing the readings to be made with perfect accuracy. As an additional aid to easy and correct reading from a distance the dial is made of translucent material, illuminated from the rear, while the marking are distinct and the figures large

and prominent. The lamp for illuminating this scale are inclosed in a compartment separate from the rest of the mechanism, giving perfect ventilation and not heating the working parts.

In this type an electro-magnet produces a shifting magnetic field, in the air gap of which is an aluminium disc in which currents are induced by the field, resulting in the disc's movement. This motion being opposed by a spring, the amount of deflection is shown by a pointer mounted on the shaft of the disc. When the pointer is at the zero position, the outline of the disc being spiral, the air gap closes that portion of the disc having the longest radius. As the deflections increase the inclosed radii decrease, diminishing the pull on the disc until it becomes proportional directly to the current, resulting in a uniform scale of a length obtained in no other type.




These instruments are absolutely unaffected by external fields, are totally dead-beat, and are compensated for changes in temperature and frequency. The moving elements being very light in weight, the bearings perfect, finely ground jewels and the shaft carefully hardened and polished, renders friction a negligible quantity. Made to certified and legal standards, they are calibrated with extreme care. The parts are interchangeable, and the cases dust-proof and of neat appearance.

Instead of requiring the main current to be brought to the instrument, necessitating in some cases expensive bus-bar connections, this make of ammeter is arranged to operate from 5 ampère secondaries of series transformers, thus enabling the instrument to be mounted at any convenient point.

## INDUSTRIAL NOTES.

THE EMPIRE STATE-IDAHO MINING AND DEVELOPING CO., of Spokane, Wash., have purchased of the Westinghouse Electric and Mfg. Co. three motors for driving concentrating mill machinery and a large air compressor in the Coeur d'Alenes. These motors will be supplied with power from the 2,300 volt secondary circuits of the Washington Water Power Co., of Spokane, whose 50,000-volt transmission line is now extending into the Coeur d'Alenes in Northern Idaho, a distance of approximately 90 miles. There are two 150 horse power, three-phase, 2,300 volts, 589 R.P.M., type "C" induction motors to be supplied; one for driving the air compressor of the Empire State mine at Wardner, Idaho; the other to operate the Sweeney concentrating mill, a short distance from Wardner. The third motor will be of the Synchronous type, 240 horse-power, 2,300 volts, three phase, 514 R.P.M., and will drive the concentrating mill of the Tiger-Poorman mines at Burke, Idaho. These motors will be placed in operation about June 1, 1903.

WE have received from MR. F. BEHREND, New York, a pamphlet on stoneware apparatus for chemical and electrochemical purposes. Mr. Behrend is the sole importer of the high grade, acid-proof stoneware apparatus of the United Stoneware Works, Ltd., of Berlin-Charlottenburg, which is the consolidation of L. Rohrmann, E. March Sohne, Thonwarenwerk Bettenhausen, and A. Kypke. The pamphlet contains brief, illustrated descriptions of various apparatus.

THE UNION IRON WORKS, of San Francisco, is installing a power transmission plant near Reward in Inyo County, California, from which it will transmit power electrically over a distance of about 2 miles to the mill of the Reward Gold Mining Co., where induction motors will be used to drive a 20-stamp mill, an air compressor and a rock breaker. The apparatus, which has been purchased from the Westinghouse Electric and Mfg. Co., includes a 120 kilowatt, three phase alternator; a 2 horse power exciter; a type "G" switchboard panel, including voltmeters, ammeters, rheostats, etc.; two 50 horse power, type "C" induction motors, complete with auto starters, slide rails, etc.; a 15 horse power induction motor; three 7½-kilowatt OD transformers, two 1 kilowatt OD transformers, and 8 lightning arrester units. The transmission will be at 2,300 volts.

THE steam turbine plant of the Hartford Electric Light Co., Connecticut, which at present consists of a 2,000 horse-power set, is soon to be duplicated by machines built by the contractors for the original installation, the Westinghouse Machine Co. This was the first American plant where steam turbine units of large size were installed, and their complete success must be highly gratifying to the makers. In its application to the generation of electrical power the Westinghouse steam turbine is undoubtedly making marked progress, and in many instances is displacing the reciprocating steam engine for this class of work. As an evidence of this and the energy with which the manufacture of these machines is being taken up, it is stated that the aggregate power of steam turbine sets completed, in hand and in order to the Westinghouse Machine Co. does not fall far short of 200,000 kilowatts.

TRADE CATALOGUES.—We have received the following trade catalogues and pamphlets: From Ebner & Arnend, New York, an illustrated pamphlet on their goods exhibited during the recent convention of the American Electrochemical Society, also their price list of minerals; from the Yaguy Copper Co., New York, a very neatly printed and illustrated book, containing their initial report to the stockholders, with the report of H. I. Willey, engineer of mines; from the Boston Pottery Co., their catalogue No. 2 on their standard Akron stoneware; from the C. W. Hunt Co., West New Brighton, N. Y., catalogue 032 on foundry ladle cores and pamphlet 033 on coal handling machinery; from the Fort Wayne Electric Works, bulletin 1039 on small direct current generators, 1040 on motor starting rheostats, and 1041 on direct current belted motors, and from the Electrical Appliance Co., of Chicago, a well illustrated catalogue on conduits and conduit fittings.

## *Personal.*

MR. THOMAS A. EDISON has accepted the position of honorary chief consulting electrician to the St. Louis Exposition.

MR. JOSEPH B. HAYS is now chief engineer of the McGraw Mfg. Co. of Chicago, having severed his connection with the General Electric Co.

AMONG the active members of the Bach choir at the recent Bach festival, held at Bethlehem, Pa., from May 14th to 16th, we noticed Prof. J. W. Richards and Prof. W. S. Franklin of Lehigh University, and various engineers of the Bethlehem Steel Works.

PROF. R. LUGGIN, best known as the author of an elementary German treatise on electrochemistry, which has also been translated into English, died recently in Berlin.

PROF. J. J. THOMSON, of Cambridge, has arrived in this country for the purpose of delivering a course of lectures on the electronic theory before several universities.

Messrs. E. P. Roberts & Co., consulting engineers, of Cleveland, Ohio, have opened a branch office at 25 Broad street, New York City. Mr. William C. Andrews will be the manager of the New York office.

Mr. E. O. Ensor has been elected secretary and treasurer of the Bendit Mercantile Engineering Co., successors to Lanfketter-Bendit Mercantile Engineering Co., of St. Louis, Mo. Mr. F. C. Lanfketter retires to become president of the Victor Mfg. Co., of the same city.

## DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

*This digest of electrochemical United States patents prior to July, 1902, will be one by classes, setting out for comparison in each class those devices which have the same object, or those methods which seek the same results. In each class the patents will be arranged chronologically. The digest will be complete in the sense of covering every point which is touched upon in the original specification.*

*Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.*

### Bleaching and Disinfecting Liquids.

294,619. March 4, 1884; E. Hermite, Paris France.

Electrolyzes an alkali chloride, especially sea salt, in a diaphragm cell, with electrodes of lead, obtaining caustic and lead chloride. The lead chloride "is mixed with water and a small quantity of hydrochloric acid, and subjected to electrolysis in the presence of textile fabrics," etc., preferably in a rag engine. A lead plate on the bottom of the engine serves as cathode, receiving the deposited lead. Over this is an insulated sheet of wire gauze. Above the gauze is the insoluble anode. Bleaching effected by the chlorine water produced. May substitute zinc, iron or tin for the lead anode, to electrolyze the alkali chloride, and then electrolyze the resulting zinc, iron or tin chloride to produce the chlorine solution.

378,681. February 28, 1888; E. Hermite and C. F. Cooper, Pownall road, Dalston, Middlesex, England.

Produces hypochlorites by electrolyzing chlorides. Anodes, horizontal tubes of platinum, metal-lined with platinum, plumbago purified by boiling in a mixture of hydrochloric acid and potassium chlorate, or glass, porcelain or hard rubber faced with plumbago. Cathodes, cylindrical rods of zinc which reciprocate through the tubes, leaving an intermediate space for the electrolyte. Scrapers bear on the zinc cathodes, to remove any deposit (magnesia). Bleaching solution continuously circulated between cell and bleaching vessel.

379,465. March 13, 1888; E. Hermite and C. F. Cooper, Dalston, Middlesex, England.

Produces magnesium hypochlorite by electrolyzing its chloride. Bleaching solution continuously circulated between cell and bleaching vessel. Anodes, a series of vertical platinum sheets, stiffened by a non-conducting frame, or plates coated with platinum. Cathodes, disks of zinc fixed on a horizontal shaft and revolving between the anodes. Scrapers remove the deposited magnesia.

381,372. April 17, 1888; E. Hermite and C. F. Cooper, Pownall road, Dalston, Middlesex, England.

Electrolyzes chlorides between trough-shaped anodes of platinum, purified plumbago or glass, etc., faced with plumbago, and horizontal, revolving zinc cylinder cathodes, in each trough. Scrapers bear on the cathodes to remove deposit.

382,159. May 1, 1888; E. Hermite, Paris, France.

Electrolyzes a 5 per cent. solution of magnesium chloride and adds some magnesia. Anodes and cathodes, alternate vertical plates of platinum and zinc, respectively. A copper rod terminal is soldered to the end of each anode. The anodes are supported in wooden frames, molten sulphur being run in around the terminals. Hanks of yarn to be bleached are supported above the electrodes, on a vertically-reciprocating frame. The current is occasionally reversed to detach any deposit from the zinc cathodes.

390,325. January 15, 1889; Arthur Brin, Brompton Crescent, Middlesex, England, and Leon Q. Brin, Paris, France.

Passes a mixture of chlorine 10 per cent., and oxygen 90 per cent., through an ozonizer and then into a pulp-beater engine. Produces gas mixture by forcing oxygen into a heated retort containing manganese peroxide and hydrochloric acid.

398,045. February 19, 1889; Eugene Hermite, Edward J. Patterson and Charles F. Cooper, London, England.

Electrolyzes magnesium chloride. Rectangular cell divided by a transverse, vertical partition having an opening containing alternate, vertical plate electrodes. Platinum anodes. Zinc cathodes, each embraced by a pair of scraper blades. All the scrapers are fixed in a vertically-reciprocating frame. A propeller, placed in an opening in the partition below that containing the electrodes, causes the electrolyte to circulate between the electrodes.

471,454. March 22, 1892; Albert E. Woolf, New York City.

Electrolyzes sea water. Cathode, parallel, perforated plates of carbon, between which is the platinum anode. Injects air into the space between cathode plates, by a perforated pipe coil.

522,839. July 10, 1894; Oskar Knofler, Charlottenburg, Germany.

Bipolar electrodes, each consisting of a number of square carbon or platinum panes, set in a frame of iron, covered by hard rubber, or clay, glass, celluloid, or water-proofed wood. Electrodes clamped in series, the cell resembling a filter press. Cell compartments may be independent or connected in series.

541,147. June 18, 1895; Henry Blackman, New York City.

Electrolyzes sodium chloride and runs hypochlorite into pulp-beater engine, where it is heated by injected steam. Spent solution cooled, strengthened by fresh brine and returned to cell. May place cooling pipes in the cell itself. Anodes of platinum; cathodes of zinc.

553,465. January 21, 1896; Eugene Hermite, London, England.

Passes sea water, or a solution of sodium chloride with a little magnesium chloride, through a series of cells, each consisting of a vertical glass tube with its ends closed by plugs, through which pass the glass inlet and outlet pipes. Anodes, platinum; cathodes, zinc. Hypochlorite delivered into a receiving tank having a float which controls the supply of electrolyte and electricity.

558,240 and 558,241. Charles N. Waite, Rumford Falls, Maine, assignor to the Electro-Chemical Co., Rumford Falls, Maine.

Removes caustic solution, containing some sodium chloride, from cathode compartment of a diaphragm electrolytic cell, and uses in a wood-fibre digestor. The soapy liquor from the digestor, containing salt and the excess of caustic, is evaporated and the resulting black ash roasted and leached with water. The sodium carbonate first dissolves and may be separately recovered. The subsequent solution is treated with quick lime and returned to the cathode compartment of the cell. May causticize the entire leach solution, and return to the cell. In either case, add sufficient salt to maintain strength of solution.

559,454. May 5, 1896; Carl Kellner, Vienna, Austria-Hungary.

Runs caustic solution from electrolytic cell into an open vessel, where it is agitated to remove the hydrogen, and then down through an absorption tower. Injects the chlorine upward through bottom of tower. Uncombined chlorine forced into bleaching vessel by an ejector pipe, which sprays the bleaching liquid into the chlorine. Adds some hydrochloric acid to the brine electrolyte. The absorption tower may be filled with limestone to produce hypochloric acid.

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### HOW OTHERS SEE US.

In this issue we conclude our translation in abstract of the long report presented to the German Bunsen Society by Prof. F. Haber on electrochemistry in the United States. On his extended trip through this country last year, Dr. Haber has studied carefully and with open mind the methods of teaching chemistry and electrochemistry in various American universities and the development of industrial electrochemistry throughout this country. His report is one of the ablest and most complete papers which have been published on this subject, and is extremely suggestive on account of many remarks of a critical and general nature which Dr. Haber makes on the processes which he describes.

It is always of great interest to learn how others see us; and it is peculiarly interesting to read what a distinguished representative of the modern German scientific school of electrochemistry and physical chemistry has to say on the development of industrial electrochemistry in this country. The series of critical notes, contributed to our columns this month by various prominent American electrochemical engineers and scientists on special points in Dr. Haber's report, show that his report has been studied with great interest in this country. In such a young industry and science as ours it is impossible to expect uniformity of opinion concerning details of processes; and we hope to be able to continue in future issues the discussion of various questions which may be raised in connection with Dr. Haber's report. Probably the weakest point in the report is to be found in those few cases in which, as one of his critics puts it, Dr. Haber has practised the scientific use of the imagination to fill up gaps in his information; and it is greatly to be regretted that for commercial reasons we may be sure that just these points will never be criticised or corrected.

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### ELECTRODE POTENTIAL.

In this issue we publish an article by Mr. Woolsey McA. Johnson on the electrode potential or electrode voltage. The author has written this article with a special view of interesting practical electrochemical engineers and calling their attention to the important advantages which measurements of the electrode voltage have in practical electrolytic work. In fact, while the term electrode potential may have a somewhat novel sound to some practical men, yet measurements of the electrode potential are nothing new in certain classes of practical work; there is, for instance, probably no engineer of a storage battery concern who has not often made such measurements himself.

We may consider an electrolytic operation from the same point of view from which a business man looks at a business enterprise. We must start it in the right way, and we must

look out that the initial good conditions are maintained while the operation is going on. These nearly self-evident maxims represent, indeed, the complete solution of the problem of successful electrolytic operation. To take electroplating as a special example, it is first necessary to make up the electrolyte in the proper way; the plater must know exactly the composition of his solution, he must weigh the materials which he puts into the solution—this is just as necessary in an electroplating operation as bookkeeping is necessary to the merchant and business man. The second requirement for electroplating is that the plater knows at any time what is going on in his solution, that he keeps his solution in the good condition in which it was at the start.

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In former issues of Electrochemical Industry we have already published several articles from prominent electrochemists who know exactly what they are talking about, and who all agree that it is the cornerstone of success in practical electrolysis, after operation has been started in the proper way, to watch that the initial good conditions are maintained. There is no secret about the tendency of the electric current to change an electrochemical system through which the current passes. Some of these changes which the current produces are just what is wanted; others we do not want, but they will inevitably take place, and it is necessary to do something in order to counteract them.

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Dr. F. Haber, in his report published in this issue, goes so far as to say that often electrochemical processes, after having proven successful in the laboratory, have failed on an industrial scale for the simple reason that the experimenter in the laboratory worked with pure materials, and that in continuous industrial operation the solutions soon became impure. Dr. Haber says you can accomplish anything with pure solutions, nothing with foul solutions. It is significant that such a successful practical electrochemist as Mr. D. H. Browne concurs absolutely in this opinion of Dr. Haber's, as will be seen from some notes of Mr. Browne, also published in this issue. Indeed, theory and practice must lead to the same results, if both are on the right way; in many cases practical men and theoretical men have been equally sinners; on the one side there is too much tendency to follow the rule of thumb and to go easy, on the other side there is too much exact mathematics and not enough common sense.

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How is it possible to know what is going on in a solution during electrolysis? All the physical and chemical methods of testing are at our disposition. One of the simplest and most important instruments in this connection, however, is the voltmeter; while it primarily gives the volts at the terminals of the cell, it indirectly indicates the power which is consumed. To obtain a required number of pounds of a certain substance, by electrolysis, it is necessary to pass a certain number of ampere-hours through the cell, and as this number follows from Faraday's law, it cannot be diminished by artificial means or by inventive skill; nature requires a certain number of ampere-hours to give a certain output in pounds. But the lower the voltage at which these coulombs are passed through the cell, the smaller is the energy consumed, and it is this energy which costs money, and which is one of the most important items in the cost sheet of electrochemical operations.

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A voltmeter across the terminals of an electrolytic cell thus indicates the total energy consumed in the cell, and a voltmeter across the terminals of a storage battery, discharged at constant current, indicates the energy given out by the battery. Now, in the latter case, the electrochemical process at the electrodes consists in the change of lead peroxide into lead sulphate at the anode. When either the anode or the cathode has been fully changed into lead sulphate, the action stops and the battery cannot give out any more energy; the e. m. f., as indicated by the voltmeter across the terminals, drops suddenly.

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It is, however, evident that this failure of the battery may be due either to the anode or the cathode having been completely changed into sulphate. The voltage across the terminals of the battery does not indicate whether the anode or the cathode has given out; but it is important to know which one is exhausted, because for practical reasons both the anode and cathode should have equal capacity and should become exhausted at the same time. It is for this reason that practical storage battery engineers determine the e. m. f. of each plate separately against a third auxiliary electrode; in other words, they determine the "electrode potential" of each plate.

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A third auxiliary electrode—the potential of which against the solution is well defined—may, of course, be applied to watch the process going on in any electrolytic cell. If, after having started an electrolytic constant current operation, we find that the e. m. f. quickly rises (meaning a sudden increase of the energy consumed), then the measurement of the electrode potential of each electrode separately tells us at which plate an important change of the conditions has taken place, so that we may act accordingly. We are thus more exactly informed concerning what is going on in the cell than by simply measuring the e. m. f. at the terminals of the cell.

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## FIFTH INTERNATIONAL CONGRESS FOR APPLIED CHEMISTRY

The Fifth International Congress for Applied Chemistry has just been held at Berlin, and, according to the preliminary reports received by us, it turned out to be an equally important and enjoyable affair. The attendance was greater than at any previous international congress of chemists, the number of members being above 2600. We regret that, owing to delays in the mail, we did not receive the complete report of the proceedings in time to publish it in this issue, but may give here a preliminary summary of the work of the Congress as a whole, and of that section which is of special interest to our readers, *i. e.*, section X., devoted to electrachemistry and physical chemistry.

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There were three general meetings, in which all the members of the congress participated. The first was taken up by the numerous speeches of welcome; the second was devoted to the reading of papers of general interest by authors of international fame; at the third general meeting a number of resolutions were voted on concerning the standardization of certain analyses and concerning uniformity of chemical nomen-

clature. A list of the most important units of physical chemistry and electrochemistry—nearly throughout agreeing with the usual German notation—was proposed and submitted to the German Bunsen Society, in order to suggest amendments to the standing committee of the International Congress.

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The authors of papers, read before the second general meeting of the Congress, represented various countries, none, however, being from the United States. The speakers were Prof. Henry Moissan, of Paris; Sir William Crookes, of London; Prof. J. H. Van't Hoff, of Berlin; Mr. Ernest Solvay, of Brussels; Prof. C. Engler, of Karlsruhe, and Prof. G. Kraemer, of Berlin. Prof. Henry Moissan read the first paper, on metallic hydrides; he gave a review of the work of Wurtz, Winkler, Guntz and himself in preparing the various hydrides of metals and described their properties; from the fact that they are non-conductors of electricity, he concludes that hydrogen has no metallic character.

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Sir William Crookes, of London, followed with a highly interesting lecture on modern views on matter—the realizations of a dream. He mentioned that in 1809 Sir Humphry Davy already spoke of "radiant matter"—although in a sense somewhat different from that in which it is now used—and that he foresaw the modern science of radiation and the theory of electrons, in his statement that if particles of gases were made to move in free space with an almost infinite velocity, *i. e.*, to become radiant matter, they might produce the different species of rays so distinguished by their peculiar effects. Some prophetic statements of Faraday were also quoted. In 1879 Crookes himself advanced the theory that in the phenomena of the vacuum tube at high exhaustion the particles constituting the cathode stream consist of fragments of matter, ultra-atomic corpuscles, minute things, very much smaller, very much lighter than atoms, things which appear to be the foundation stones of which atoms are composed. Thus, we actually reach the borderland of science—where matter and force seem to merge into one another. Sir William sketched the development of the electron theory in recent years, and pointed out its enormous scientific importance, but at the same time he reminded his hearers that it must never be forgotten that theories are only useful as long as they admit of the harmonious correlations of facts into a reasonable system. Prof. J. H. Van't Hoff spoke on the formation of the salt beds, found in nature, his conclusions being based on his own investigations of the Stassfurt salts. Mr. Ernest Solvay gave some historical notes on his well-known soda process. Prof. C. Engler gave a review of the problem of autoxidation, and Prof. G. Kraemer gave a summary of the development of the tar industries.

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The main work of the Congress was done in eleven sections, the tenth of which was devoted to electrochemistry and physical chemistry. The annual convention of the German Bunsen Society was combined with the meetings of this section. A great number of papers were presented. J. Traube explained his views on the conditions of gases and fluids; he assumes that fluids contain two kinds of molecules which he calls fluidons and gaseons, while gases contain only the latter Tammann, in the discussion, did not consider the experiments described by the author to be decisive for the correctness of his theory. Prof. W. Nernst described his apparatus for determining vapor densities at very high temperatures, known to our readers by the author's paper read on the same subject at the recent New York meeting of the American Electrochemical Society. Froelich described a new form of a resistance furnace, Wedekind spoke on colloidal zirconium and Marie on electrolytic reduction. Two extensive reports were presented by Foerster and Brandeis on the industrial application of electrolytic methods to the preparation of inorganic compounds.

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LeBlanc gave an account of an investigation of electrolysis by alternating currents; that electrodecomposition takes place is due to the fact that the processes at the electrodes are not exactly reversible. For instance, when the current flows in one direction, metal is deposited, and when the current is then reversed, the metal is not redissolved, but, perhaps, something else; it seems possible to use such experiments to draw conclusions on the speed of ionic reactions. Lebeau spoke on electrometallurgical products, Gin on the manufacture of aluminium, and Coehn on the influence of the material of which the electrodes consist, on the process of electrolytic oxidation and reduction; two different influences must here be distinguished: the over-voltage, which is different at different materials, and catalytic influences on the reaction. Goldschmidt gave a review of the various electric iron and steel processes which have been tried on a large experimental scale, and Mr. Edw. R. Taylor, of Penn Yan, N. Y., presented a paper on his process of making bisulphide of carbon in the electric furnace. Kuester read a paper on the dissociation pressure, and Guntz on the preparation of barium. Schenck presented the results of his experiments on the decomposition of carbon monoxide into carbon and carbon dioxide in contact with platinum asbestos, and Bodenstein and Bodlaender read two papers on the speed of formation of sulphuric oxide from sulphurous oxide and oxygen in contact with platinum wire. Zengelis spoke on chemical reactions at very high temperatures, Goldschmidt on the kinetics of reduction phenomena, and various elaborate reports were presented by Elbs and Buchner on electrolytic methods for preparing organic compounds, by Bodlaender on applications of catalytic action on various problems of organic and inorganic chemistry, Sackur on the installation of electroplating plants for plating great quantities of small objects, Danneel on quantitative separation and deposition of metals by electrolysis.

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While for details we must refer our readers to the full report which will be published in our next issue, the above brief sketch of the work of the electrochemical section alone, together with the enormous number of members inscribed, proves that the Congress has been a gratifying success. The benefits of a reunion of chemists from all countries of the world are not alone social. Although the general principles of chemistry are the common property of chemists in all countries, yet the differences existing in the different countries in political, commercial and social respect, have caused chemical industries to develop on different lines in different countries. An international congress offers to chemists an opportunity to learn to understand and appreciate the difficulties and problems which their professional brethren have to face in other countries.

## INTERNATIONAL CONGRESS FOR APPLIED CHEMISTRY.

The Fifth International Congress for Applied Chemistry was formally opened on June 3. Prof. O. N. Witt presided, and a great many leading authorities on chemistry from all parts of the world were present. Speeches of welcome were delivered by Count Posadowsky, Imperial Secretary of State for the Interior, and Dr. Studt, Prussian Minister of Education. Among the foreign delegates who delivered addresses were Prof. Moissan, of Paris; Prof. Tilden, of London; Prof. Ludwig, of Vienna, and Prof. Clarke, of Washington.

About 2,600 members were present, and there were 350 papers and reports on the programme. The Congress was divided into eleven sections and three sub-sections, section X being devoted to electrochemistry and physical chemistry. The German Bunsen Society also held its annual meeting at Berlin during the same week, and took charge of the electrochemical section. An editorial comment on the work of the Congress is found on another page.

## AMERICAN ELECTROCHEMICAL SOCIETY.

At the Board Meeting of the American Electrochemical Society, held at Philadelphia on June 13, the following gentlemen were elected members of the Society: F. E. Drake, New York; I. J. Moltkehansen, Perth Amboy, N. J.; F. T. Snyder, Oak Park, Ill.; Dr. H. Reisenegger, Augsberg, Germany; Robert Spice, New York; Dr. Leo Boekelard, Berlin, Germany; H. Wigglesworth, New York; H. J. Lucke, Washington, D. C.; S. W. Traylor, New York; Dr. Paul Askenasy, Nuremberg, Germany; Dr. Rudolph F. Gahl, Philadelphia, Pa.; N. B. Cornwall, Princeton, N. J.; B. F. Thomas, Chattanooga, Tenn.; H. A. Jackson, New York; C. E. Speirs, New York. The fall meeting of the Society is to be held at Niagara Falls, from Sept. 17 to 19.

## FIRST ANNUAL REPORT OF THE INTERNATIONAL NICKEL COMPANY.

The first annual report of the International Nickel Co. (which owns the Canadian Copper Co., the Orford Copper Co., the American Nickel Works in the United States, the Nickel Corporation, Ltd., the Société Minière Caledonienne in New Caledonia, a large interest in the Société Le Nickel, etc.,) covers the year ending March 31, 1903. The profit account shows earnings of constituent companies, less selling and administrative expenses, $1,090,401; interest, $29,016; total, $1,119,417. On the other hand, the general expenses were $110,024; the interest on bonded debt, $450,244; total, $560,268; so that the surplus for the year amount to $559,149. The accounts of the New Caledonia companies were not received in time to be included in the above account.

The directors' report states that a careful examination of the various manufacturing plants has shown them to be in very bad condition, nearly all the machinery being very old and much of it obsolete, expensive to maintain and operate. Expenditure for repairs on the Canadian, the Orford and the American Nickel Works was $225,435 during the year; this is excessive and should eventually be largely reduced. The intention is to reconstruct the plants of the constituent companies, bringing them up to the highest standing of metallurgical and economical efficiency. During the past year only such improvements have been made as were absolutely necessary to keep these plants in successful operation and produce the required amount of metals, the changes made being such as would fall within the general scheme of reconstruction.

At the Ontario works of the Canadian Copper Co. a third Browne calcining furnace of larger capacity than the two furnaces there in operation has been installed. The older furnaces have been increased to 40 feet in length, a cooling device, conveyors and a briquetting plant to handle mechanically the product of 12 calcining furnaces, are now being installed. These improvements, now nearly completed, will double the capacity of the plant and materially reduce the cost of treatment per ton.

At the Orford Copper Co.'s works a new nickel refinery has been erected to provide the increased quantity of nickel required as metallic nickel, and to reduce the cost of refining; the old nickel refinery has been abandoned.

A new smelting plant is built at the Orford Copper Co.'s works in Canada. The new works will be equipped with the best and most economical steam and power plants, blast furnaces, ore and matte handling devices, together with new locomotives and proper cars for handling the ore to the furnaces. The cost of this plant is estimated at $500,000, and the estimated saving is $200,000 to $250,000 a year. It is expected that the new plant will be in operation within one year from the present time. When this improvement is completed the Orford Copper Co.'s works will be reconstructed on modern lines, thereby effecting a very large saving.

Efforts are being made to introduce nickel into new fields and to extend its use in old lines, particularly to extend the use of nickel-steel. The results have already been very gratifying; about 12,000 tons of steel rails, 3.25 per cent. nickel, have been purchased by the American railways, and are nearly all manufactured. Seamless drawn tubes, containing a high percentage of nickel, have been successfully manufactured, and an important market is expected for these tubes. It is also probable that within a very short time nickel-steel will be largely used in bridge construction.

In connection with this official report, it will be of interest to read the remarks of Dr. F. Haber on the nickel industry in general, and particularly on the Browne process, published on another page of this issue.

Liebig Celebration.—A large number of members of the American Chemical Society, the American Electrochemical Society, the Chemists' Club, and the New York Section of the Verein Deutscher Chemiker participated in the centennial celebration of the birthday of Justus von Liebig, held in the assembly hall of the Chemists' Club in New York City on May 12. Dr. Ira Remsen, of Johns Hopkins, delivered the first address, in which he gave an outline of the life and work of Liebig and recorded some personal reminiscences of the time when he attended Liebig's lectures at Munich: Liebig used to illustrate his lectures by extremely elaborate experiments, and was always fond of dramatic effects, a most effective experiment being usually reserved for the conclusion of the lecture. The second address was delivered by Prof. William H. Brewer, of Yale, who is the oldest living pupil of Liebig in the United States. His address was full of personal reminiscences; he had read in 1846 Liebig's book on agricultural chemistry, and in his desire to study under him he came to Munich. The late Ogden Rood (afterward professor at Columbia) advised him that it was extremely difficult to get admission to Liebig's laboratory as a student; he advised him not to use his letters of introduction, not to call Liebig "Herr Professor," but "Herr Baron," and not to spare flattery. Brewer, when introduced to Liebig, followed this advice, but Liebig told him he would better go somewhere else, as he could give him no attention whatever. Brewer finally said that he came three thousand miles to sit at the feet of the greatest teacher of chemistry in Europe, and that he had come to stay there. Then he was admitted to the laboratory, where he remained for a year, but received practically no attention from Liebig, just as the latter had promised. The last speaker was Dr. Carl Duisberg, director of the Elberfeld Color Works, who spoke on Liebig's influence on chemical industry. It is to be placed mainly to Liebig's credit that scientific chemical investigation displaced the rule-of-thumb in all the great chemical industries of Germany, and to some extent his influence was also felt in other countries. His influence was greatest, however, on organic chemical industries.

## OONATIOFNTHE OXIDSILOXICON.

By Edward G. Acheson.

The descriptions of the new refractory substance, siloxicon, that have recently appeared in the technical press and in the newspapers have created such a widespread interest, as evidenced by the numerous inquiries received from all parts of the country and all lines of industry, that it is desirable to correct a statement that was contained in these publications.

It was there stated that siloxicon was inoxidizable, but recent investigations have shown that this is not true. When it is heated to, or above, 2674° F. in an atmosphere containing a large amount of free oxygen decomposition occurs.

Siloxicon, while variable in composition, may be represented by the formula $Si_2C_2O$, and when heated, as above stated, in presence of free oxygen, decomposition takes place, probably in accordance with the following equation:

$$Si_2C_2O + 7O = 2SiO_2 + 2CO_2.$$

If the siloxicon be in the form of a brick or other molded mass the reaction occurs on the surface, producing a vitreous glaze, which in most instances is tinged light green from the presence of iron.

In the absence of free oxygen or in a reducing atmosphere no such decomposition occurs, and the temperature may be raised to the point of the formation of carborundum, or, approximately 5000° F., before any change occurs, and then it takes place, it is thought, in accordance with this equation:

$$Si_2C_2O = SiC + Si + CO,$$

solid carborundum remaining, while the vapors of silicon and carbon monoxide are given off.

It is interesting to note that after having discovered this oxidation of siloxicon, tests were made with carborundum, and it was found to be affected in a manner exactly similar to siloxicon; this notwithstanding the fact that for more than twelve years it had been generally considered inoxidizable.

## ELECTRODE VOLTAGE OR ELECTRODE POTENTIAL.

By Woolsey McA. Johnson.

The Electrochemical Industry has received so many enquiries as to the term "electrode voltage" and "electrode-potential," used in previous articles by me, that it is thought that a short paper explaining this term will be not without interest to its readers, or at least to those readers engaged in practical work in the electrolytic deposition of metals.

The phenomena of electrolytic dissolution, electrolytic conduction, and electrolytic deposition, simple as they seem to those of us who see the concrete facts daily, are really of the deepest nature and underlie many complex facts. When we know more of the mechanism by which these simple changes are affected, then we will know better the relation between electricity and matter. Any digression into the realms of the "electron" theory is outside of the bounds of this article, which is a review of our present experimental knowledge of electrolytic action at the cathode and electrolytic action at the anode, combined with some explanations of the experimental facts.

Let us consider a cube of one centimeter dimension made by two platinum electrodes dipping in a 5 per cent. solution of sulphuric acid. This has a resistance of about five ohms at room temperature. If the laws of metallic conduction held, on impressing a voltage of 0.50 volts a current of 0.10 ampere would flow through the circuit, and on doubling the voltage the current would double. Thus the curve of the relation between voltage and current would be absolutely a straight line, as is demanded by the simple relation known as Ohm's law.

$$\text{Amperes} = \frac{\text{volts}}{\text{ohms}} \quad \text{(see Fig. 1.)}.$$

Now, no such curve, as found for the laws of metallic conduction, holds for electrolytic conductors, the curve in the latter case being not a straight line but having rather a boomerang shape. (See Curve II., Fig. I., taken from experimental work done by me.) It is seen that below a certain point, P, on the curve very little current passes through the above-mentioned electrochemical system, but that when a certain critical point, P, is reached the current starts to flow quite rapidly. This point P is about 1.67 volts for 5 per cent. $H_2SO_4$. Below 1.67 volts the current is slight. Above this point the current starts and is found to be roughly proportional to the voltage impressed less 1.67 volts.

The system acts very much like a safety-valve set to blow off, we will assume for sake of simplicity, at 167 pounds to the square inch. The safety-valve leaks so that a little steam will pass through it while the pressure is around 100 pounds. But this steam that passes through is small in

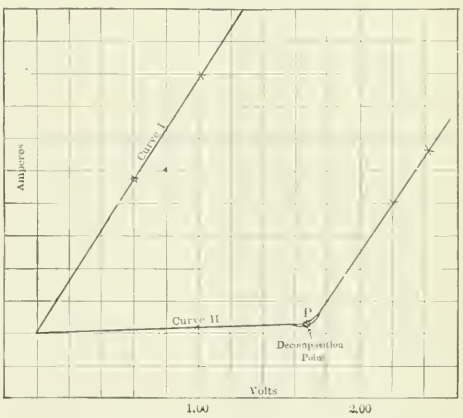



FIG. I. METALLIC AND ELECTROLYTIC CONDUCTION.

quantity compared with the steam that rushes out when the critical pressure of the safety-valve, 167 pounds, is exceeded by that of the boiler. The curve of the flow of steam as affected by pressure would be like that of the decomposition voltage curve II. of Fig. I.

Again, heat water under atmospheric pressure practically very little steam is evolved until the temperature of the water is 100° C. Then the dissociation of the water molecules into the simple gas molecules generates pressure large enough to drive off continuously the steam into space. The phenomenon is the same in all three cases; a certain critical pressure must be overcome, then the transfer of matter is proportional to some function of the effective pressure. By effective pressure is meant the impressed pressure less the critical counter pressure.

Now, we see that the electrochemical system possesses no wonderful characteristics that make its action different from that of any other system, but that it acts simply in accordance with general laws that govern the transfer of matter.

We must modify Ohm's law for electrolytic conduction.

$$\text{Amperes} = \frac{\text{volts impressed} - \text{critical voltage}}{\text{ohms}}$$

or

$$\text{Amperes} = \frac{\text{net volts}}{\text{ohms}}$$

This critical voltage, or voltage of "polarization," is the number of pounds at which the nature of the electrochemical system, cathode-electrolyte-anode, sets our electrochemical safety-valve. Vary these and we have a different value for the

critical voltage. With platinum electrodes, the voltage is 1.67 volts. With lead electrodes the voltage is 1.90 volts. Change the acid to normal hydrochloric acid and the voltage is 1.31 volts.

The term "critical-voltage," or "decomposition-voltage" (*Zersetzungsspannung*) is preferable to the term polarization, because polarization is a term used in electromagnetism, and in optics to entirely different phenomena.

The "critical-voltage," or "decomposition-voltage" is made of two voltages, or potentials, viz: The "electrode-potential," or "electrode-voltage" at the cathode and the electrode-potential at the anode. We must make the assumption that the electrolyte is of uniform composition and consequently exclude the disturbing factor of voltages due to differences of concentration in the electrolyte.

We can express this as follows: Critical voltage = anode voltage + cathode voltage or electrode voltage:

$$E = e_a + e_c$$

To measure these two voltages we must have some standard electrode that is called zero, as we assume the pressure of the atmosphere is equal to zero when we measure the pressure of the boiler.

Two arbitrary standards have been proposed:

First, that the KCl—n, $Hg_2Cl_2$, Hg system, called the "calomel-electrode," be placed at —0.560 volt.

Second, that the $H_2SO_4$ (normal as regards the hydrogen ions) $H_2$, Pt system be placed at 0.00 volt.

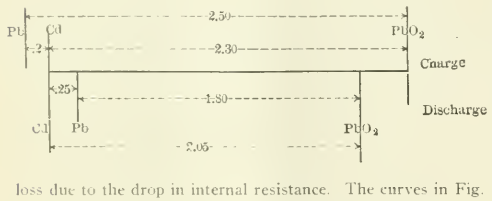
Both these have advantages for scientific investigation, but both are of little use for practical work. Zinc, cadmium, copper auxiliary test electrodes are easy to make and use, and are fairly steady. While not accurate to the millivolt, they are sufficiently accurate for working conditions. Their values can be referred to the above standards, either experimentally or by referring to the literature on the subject.

It is apparent that the critical voltage of any system is made up of the algebraic sum of the anode and cathode voltage. It is immaterial whether this system be made artificially as in the primary cell, or electrochemically as in the secondary cell.

In the secondary cell, the best type of which is the familiar lead accumulator, we have electrolytically reduced lead as anode on the discharge and electrolytically formed peroxide of lead as cathode on the discharge. The apparent ampere density is small and the internal resistance small. Consequently the CxR loss in all is small and the drop across the terminals is almost entirely due to the sum of the two electrode potentials. This voltage is a measure of the intensity of the anode to combine with anolyte and cathode to combine with catholyte.

To separate the two, we measure the electrode against a cadmium electrode or a zinc electrode.

These values, taken from Lyndon's new book, "Storage Battery Engineering," are read on discharge, and include the




loss due to the drop in internal resistance. The curves in Fig. 2 (taken from Dolezalek, *Die Theorie des Bleiaccumulators*) show that the peroxide plate is less reversible than the lead plate. This is due to the fact that lead is a better metallic conductor than lead peroxide. It is easy by means of the auxiliary electrode to see which plate is giving out first.

The sharp jump at the end of charge is due to the fact the system has been charged and we have a different stage of oxidation. This is sharper when the accumulator is charged at low current densities. The sharpness of the bend is a measure of the excellence of the accumulator. The sharper the curve the more reversible the cell.

In the case of the reversible copper-oxide, respectively copper plate, there are several of these jumps due to the fact that the active material of the plate is susceptible of several states of oxidation. Each oxide of copper has its own electrode voltage, and the jumps are due to the changes from one oxide to the next higher (see W. McA. Johnson, *Transactions of American Electrochemical Society*, Vol. 1., No. 1., p. 187). If we raise water by means of a pump to a series of barrels

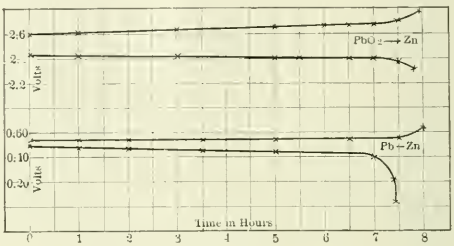



FIG. 2.—LEAD ACCUMULATOR.

placed at different levels, say 30 feet difference, the pressure pump must overcome to raise water is first fifteen pounds. When the first barrel is filled, the pressure rises immediately fifteen pounds, and so on through the series. The analogy is complete if the barrels are of large capacity and low height. Another analogy can be drawn to the dissociation of $CuSO_4 5H_2O$. Here we have the dissociation pressure of the hydrate which can be measured in pounds to square inch, or millimeters of mercury. It is a striking instance of the similarity of different phenomena. Fig. 3 shows the different electrode voltages of various oxides of copper against the KOH, $H_2$, Pt normal electrode.

An electrochemical system can have an electrode voltage equal to zero. In this case $E = 0$, for $e_a = -e_c$. This is the case with a great number of soluble metallic anodes, and can be considered best by the familiar copper electrolysis with soluble copper anode, acidulated copper sulphate as electrolyte.

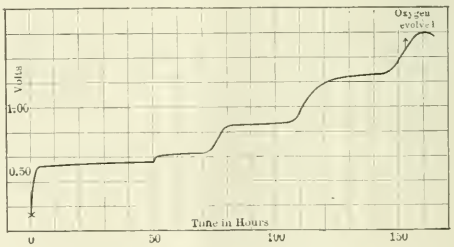



FIG. 3.—CURVE SHOWING THE DIFFERENT ELECTRODE VOLTAGES OF VARIOUS OXIDES OF COPPER.

and any metal as cathode, for the copper is immediately precipitated on the cathode, which becomes a copper cathode.

Here we have very little voltage on open circuit, for cast copper has almost exactly the same voltage as electrolytic copper. The anode voltage is equal and opposite to the cathode voltage, the small counter E. M. F. is due to concentration changes at the electrodes. Consequently a very small amount of energy is necessary to transfer a small amount of copper from anode to cathode. The state of affairs can well be described as an electrochemical "Atwood's machine," for

the flow of matter is in each case proportional to some function of the difference in pressure.

If the Atwood's machine were immersed in oil, or in some liquid that offered great friction to the weights, the analogy

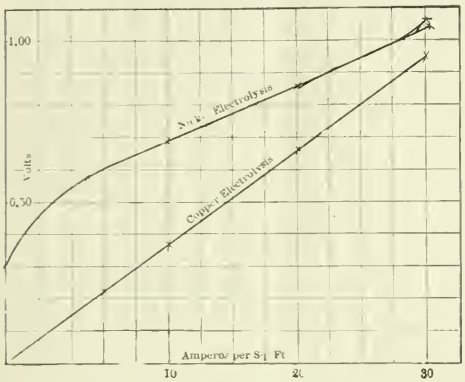



FIG. 4.—NICKEL AND COPPER ELECTROLYSIS.

would be complete, for the flow of matter would be directly proportional in each case to the difference in pressure.

In one case the difference of pressure would be measured in pounds, and in the second case would be measured in

Another instance of change in electrode voltage can be seen in the depolarizing action of liquids and gases. For example, in my article in the ELECTROCHEMICAL INDUSTRY, April, 1903, I mentioned that the use of $SO_2$ in an electrolyte of $H_2SO_4$, with $PbO_2$ as anode reduced materially the anode potential. This can be seen graphically in the curve of Fig. 5, taken from an old note-book of mine. The formation of $SO_3$ reduces the back electrolytic tension of the oxygen of lead peroxide so that the voltage is reduced by 0.50 volts. If the reduction figured on the equation $e_1 - e_2 = \frac{0.058}{n} \lg \frac{P_1}{P_2}$ it will be seen that the reduction of the electrolytic pressure would be measured in millions of atmospheres.

A number of other examples might be quoted, but these few are illustrative of others, and it is hoped will suggest to the readers others.

Subsequent articles in this series will treat the question of electrode voltage in the terms of the dissociation theory, and will discuss the various methods of measuring electrode voltage.

## EIGHTH ANNUAL MEETING OF THE AMERICAN FOUNDRYMEN'S ASSOCIATION.

The eighth annual convention of the American Foundrymen's Association was held on June 9, 10, 11 in Milwaukee, Wis., 210 members being present. The convention turned out to be a great success.

The presidential address of Mr. A. W. WALKER, of the

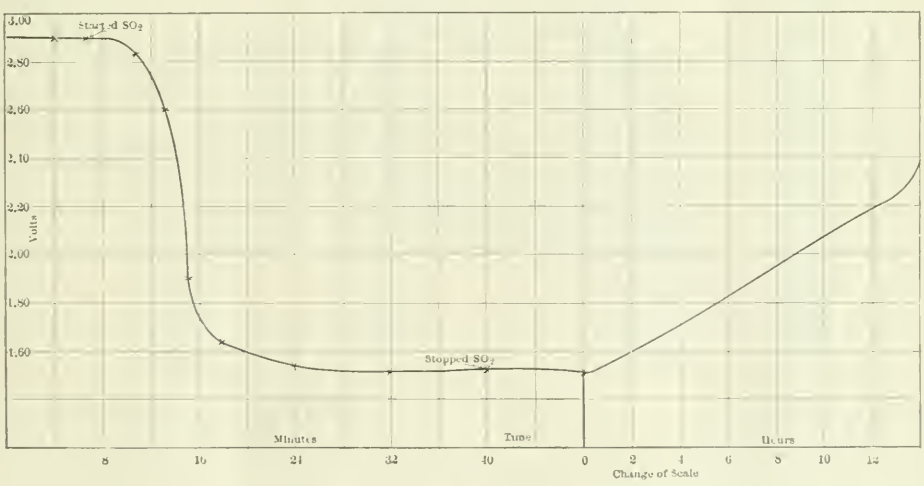



FIG. 5.—DEPOLARIZATION EFFECT OF $SO_2$.

volts. Fig. 4 shows that the "volts-amperes" curve is practically a straight line. Such a system is the most perfect reversible system that is known. The loss is due, not to polarization effects, but to the C.R loss due to ohmic resistance.

In nickel electrolytic work, the case is quite different. Here the anode of cast nickel requires electrolytic energy to break up the alloys of nickel existing in it, and it also requires more energy to deposit nickel hydride at the cathode. Fig. 4 shows the irreversibility of nickel electrolysis. The bending on the upper curve shows the polarization. In other words the electrode voltage increases with increase of current density. Of course such a perfect reversible combination as the copper electrolytic system will show polarization effects, but only at increased current density. Nickel electrolysis and copper electrolysis are markedly different in these respects.

Walker & Pratt Manufacturing Co., of Boston, dealt mainly with the *Labor Problem*. He compared the present situation in the business represented by the Association—a powerful labor organization on one side, and no less powerful associations for the defense on the other—with that of the nations of the world, with respect to their naval armament. As strong navies are a guarantee to continued peace, so large and constantly increasing funds available for instant use by these strong organizations, may insure industrial quiet. But great military and naval strength, while doubtless the most practicable peacemaker now, will in some time be obsolete for that purpose. As the increasing effectiveness of modern weapons makes war absurd, unreasonable, and, finally, impossible, so large reserve funds may in time cease to be the chief reliance in dealing with labor. The manufacturer who is wisely build-

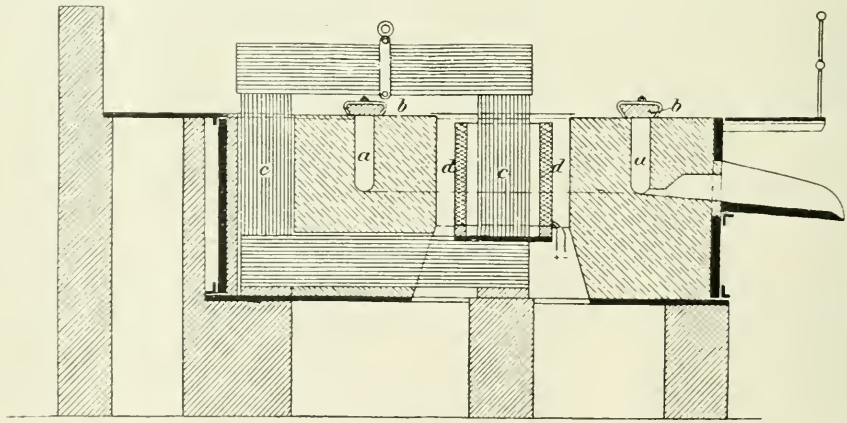
ing for the future, will study to work with his employees, rather than against them, to please them, to unite his managing ability with their muscle and skill. A first step will be to study the comfort and convenience of employees. Moreover, it will be found impossible to permanently withhold from the workmen a fair proportion of income from the manufacturing enterprise. The liberal-minded manufacturer will not object to an advance of wages in prosperous times. When dull times return the men must expect the inevitable reduction of wages; if they are entirely satisfied that they are based upon the true state of the business, they will accept such reductions with content.

Mr. Walker does not contend that the earnings of the men should be in direct proportion to the profits of the employer, but that earnings do and should bear some relations to profits. Many contests have arisen over this matter, some due to insufficient information, or an unreasonable concealment of real conditions by the employer. If the manufacturer would give as much time and thought to informing and educating his employees as he now spends in pleasing his customers, the effect would be helpful. Sometimes an employer may go so far in prosperous times as to distribute a portion of his profits among his men. But it is not entirely a question of money with the American mechanic. The rapid development of business has separated him from his former contact with his employer; his imperfect notion of profits and similar matters has made him discontented. The professional labor agitator is a logical product of the time; employers should make him unnecessary, and we shall hear no more of him. The manufacturers who will achieve the highest development and success during the next ten or twenty years, will be those who recognize the present conditions as temporary, and put themselves in line for harmonious and cordial relations with the men who are doing for them in factory or foundry the work which they themselves would do if the size of their enterprise would permit.

Dr. R. Moldenke, of New York, in his report as secretary, pointed out that only by educating the present and coming labor will be overcome the evils that are steadily growing and hampering the full development of the industry. To do this, one must begin at the bottom and furnish the apprentice the means to acquire the information that is to be the foundation of his life work. He recommended that short and elementary instruction papers be prepared under the direction of a special committee, and issued by the Association to the foundrymen at cost, for distribution among the employees. He also supported the suggestion made by Mr. Stanley G. Flagg, Jr., of Philadelphia, to do something in the way of original investigation for the purpose of overcoming difficulties in foundry practice. A committee was appointed, with Mr. Flagg as chairman, to take up such original investigation.

Among the papers presented at the meeting were the following: T. D. West, "A Cupola Slag Conveyor;" A. W. Walker, "Mechanical Device for Ascertaining the Average Silicon in an Iron Mixture;" J. C. Knoeppel, "The Continuous Operation of the Iron Foundry;" F. W. Stickle, "Foundry Responsibility;" R. P. Cunningham, "Foundry Control;" D. Spence, "Foundry Management;" J. A. Murphy, "Permanent Molds;" E. Richelieu, "Note on Continuous Molding;" E. Gilmour, "Molding Machines;" S. H. Stupakoff, "Molding Machines;" A. M. Loudon, "Trials of a Foundry Foreman;" J. G. Stuart, "Technical Education in the Foundry Office;" William Hanson, "Estimating Methods;" W. J. Keep, "Retort Oven Coke for Foundry Use;" R. Moldenke, "Malleable Cast Iron;" S. H. Stupakoff, "Employer and Employee;" W. H. Carrier, "Heating and Ventilating Foundries and Machine Shops on the Fan System;" S. S. Knight, "The Principal Factors of the Iron Industry in the Birmingham District;" W. E. Dickson, "Loss of Suphur in Borings of Pig Iron;" H. Souther, "The Metallurgical Engineer in the Foundry" (see Current Notes); W. W. Davies, "Blast Furnace Conditions Affecting the Chemical Composition of Foundry Iron."

Mr. Willis Brown, Walker Foundry Co., Erie, Pa., was elected president of the Association for the next year. A visit to the works of the Allis-Chalmers Co., at West Allis, a suburb of Milwaukee, on the afternoon of June 10, was greatly enjoyed by the members of the Association.




KJELLIN STEEL FURNACE.

## ELECTRIC STEEL FURNACE AT GYSINGE.

The Kjellin electric steel furnace, in operation at Gysinge, Sweden, is interesting on account of the fact that it contains no electrodes, the heat produced in the hearth of the furnace being due to currents set up in it by induction. From an article of the inventor, F. A. Kjellin, in *Jernkotorets Annaler* (see also *Glueckauf*, 1903, No. 4, p. 77), we gather the following information.

The adjoining diagram shows the general arrangement of the Kjellin furnace. The annular space *a a*, the bottom and sides of which are formed by masonry work, is the hearth of the furnace; the cover *bb* of the furnace is removable. *C* is a rectangular magnetic circuit, formed of thin, soft iron plates. The coil *d d* is connected to the terminals of an alternating current generator.

The arrangement may be considered as an alternating current transformer, the coil *dd* being the primary winding, while the secondary is formed by the material to be fused. After some preliminary experiments the first steel was produced in March of 1900; but while the properties of the steel produced were quite satisfactory, the dimensions of the furnace were too small to allow an economical operation; the furnace held only 80 kg of material, and with the 78 kw dynamo at hand not more than 270 kg of cast steel were produced in twenty-four hours.

A new and larger furnace gave considerably better results, as with a 58-kw generator 600 to 700 kg of steel were produced in twenty-four hours; the furnace held 180 kg, and for the treatment of each charge of about 100 kg, three to four hours were required. Nevertheless the output per horse-power hour was not yet satisfactory, there being great losses due to radiation; the expenses of repair of the furnace per ton of steel produced were also higher than they should be in a large furnace.

When, at the end of 1901, the re-erection of the steel works at Gysinge was undertaken, it was decided to install a 300-hp turbine directly coupled with the alternator for the steel furnace. The new furnace holds 1800 kg, and when charged with cold raw material, it is able to produce at least 1500 tons per year. The voltage of the alternator is 3000. The works are intended for the production of tool steel of the best kind and the properties of the steel made are said to be excellent, which is thought to be due to the fact that the steel is entirely free from gases.

Some interesting tests of steel made in the electric furnace at Gysinge were published by Benedicks in the *Zeitschrift f. physik. Chemie*, v. 40, 5 (an abstract of this paper being given in *Elektrotechnische Zeitschrift*, 1902, Sept. 11). This steel was found to be very homogeneous and free from gases. The results obtained by the same author on the electric resistivity of steel as a function of the composition are also interesting. Chemically equivalent quantities of different materials dissolved in iron increase the electric resistivity by the same amount, according to the following law: One dissolved gram atom per 100 gram atoms of solution increases the resistivity by 5.9 microhms for a cubic centimeter; this is correct for additions of C, Si, Mn, P, Wo, and Al. Carbide in iron has no appreciable influence. The resistivity of absolutely pure iron at ordinary temperature is 76 microhms for a cubic centimeter

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## NOTES ON A CLASSIFICATION OF ELECTRO CHEMISTRY.

BY CLINTON PAUL TOWNSEND.

(*Continued from page 237*)

### AQUEOUS BATH, APPARATUS.

Electrolytic apparatus, and more especially apparatus designed for technical work, is usually constructed for a specific purpose; accordingly the apparatus is best included with the process in its appropriate class, it being in fact often difficult to determine whether the novelty is inherent in the method or the device. Certain classes of devices are, however, capable of diverse uses, and being unrelated to any specific method of operation, are conveniently assembled in a separate sub-class. Such, for instance, are the various holders or clamps employed for separating objects in plating baths, and such elaborate machines as those used for electroplating arc carbons; the screens and patterns employed for "shadowing" articles during plating to produce deposits of unequal thickness, or to guard against marginal growths; and cells for conducting electrolytic operations under special conditions of pressure, temperature, etc. This sub-class may also include cells designed for such peculiar use as the electroplating of ships' bottoms, and provided with means for holding them in operative position.

### AQUEOUS BATH, CATHODES

The cathode, like the anode, is often merely a means for establishing a connection between the electrolyte and the generator; often, however, it is designed to accomplish quite a distinct result. For instance, it is formed for the production by direct deposition of particular articles, such as tubes, wire-bars, trolley wheels, or the air chambers of pumps; it may be prepared, as by treatment with oil, graphite, sulfur or sulfids, or by oxidation, to permit the ready stripping of a deposit, in which case metal films or "papers" may be produced, such cathodes usually taking the form of a revolving cylinder or moving belt, in order that the process may be made continuous; in some cases this preparation of a brilliant surface to which the deposit will not adhere is applied to specially designed cathodes, as, for instance, in the elaborate methods and devices for the direct production of parabolic reflectors; and in cases where a spongy deposit requires to be collected as in the recovery of tin from scrap, the form of the cathode may be adapted to this end. Again the novelty may lie merely in the form or character of the cathode, as in the copper-plating of the hulls of vessels, in which case the elaborate devices which adapt the bath to the work may be cross-referenced into this class. In general the class is intended to include reference to such electrodes as by their form, material or design are especially adapted to serve as cathode.

### AQUEOUS BATH CATHODES, METALLIZING.

Such cathodes as are referred to in the preceding section are of metal or carbon. In many cases, however, as in electrotyping methods, it is necessary to deposit the metal upon a surface which is primarily non-conducting, and such surface must therefore receive a conductive coating with suitable electrical connections thereto. Graphite and metals in a state of minute subdivision are in general the conductors used, but a vast amount of careful work has been done with a view to hardening the form or matrix to render its surface sufficiently resistant, and to prevent the penetration of the electrolyte, and for the purpose of securing an even coherent and polished coating of the metallizing agent. When graphite or metal powders are used, these are generally brushed or blown over the surface of the matrix, and the devices therefor are classified under this heading. When a more nearly absolute conformity to the original surface is required, as in the reproduction of sound records and delicate surfaces generally, recourse is had to precipitation methods in which the metal is separated from its solutions by a chemical reducing agent the methods often resembling closely the photographic development processes; or to methods depending upon the use of the static discharge in vacuo. The tenuity of the coatings produced by this latter method is extreme, and the deposits conform to the surfaces with an exactness which approaches the absolute. These vacuum deposits have been studied in other and independent relations, and, therefore, it is found advisable to establish for them a separate class with appropriate cross-references. In the case of vitrified surfaces, glass, tile and porcelain, adhesion is often secured by firing a mixture of salts with simultaneous reduction, the subsequent electro deposits being frequently of such character as to bind the pieces into a design or mosaic

### AQUEOUS BATH CATHODES, METALLIZING, POROUS SUBSTANCES

By reason of the number and variety of the published methods of metallizing non-conductors, it is found convenient to segregate the methods which are particularly applicable to porous materials, such as fabrics, a line in which some excellent work is now being done in this country Heavy fabrics, coated with copper and darkened by suitable after treatment may be used as wall coverings, while lighter fabrics or laces, stiffened by a suitable deposit, may be made into lamp-shades, etc.

### AQUEOUS BATH, INORGANIC COMPOUNDS

In addition to the somewhat extended literature relating

to the deposition of the metal and the physical characteristics of the deposit, this class is conveniently extended to include the work of Hittorf and others upon the passive state. This particular phase of the subject is, of course, bound up with the study of the passive state assumed by iron, nickel, cobalt, etc.

### Aqueous Bath, Colloidal Metals.

The electrical methods whereby the metals have been obtained in the colloidal state are distinguished from others under the general class of aqueous bath, in that they do not depend upon the electrolytic effect of the current, but on the action of a luminous arc under water or dilute aqueous solution. It is convenient, however, to extend this class to include reference to the strictly chemical methods for the production of colloidal solutions, and the action of the same under the influence of electrolytes and of the electric current. This subject is, of course, cross-referenced to or from the appropriate classes designed by the names of metals.

### Aqueous Baths, Inorganic Compounds.

The subdivisions of compounds being mutually exclusive and together covering the entire field, there is no residual or generic class. Of the inorganic compounds, those in the production of which the greatest activity has been displayed, to wit., the products of decomposition of the haloid salts, and the pigments, have been assigned to separate classes; and the sulphates are also separately classified. The remaining references, therefore, constitute a class which is by no means unwieldy, and which includes such anodic reactions as the production of manganates and permanganates, chromates and bichromates, percarbonates and pertungstates, and the formation of alums; such cathodic reactions as involve the reduction of nitrates, carbonates, etc.; and such general methods as those of Lorenz for the production of insoluble hydroxids and sulfids. These latter should be cross-referenced into the class of pigments, and, in fact, it is found convenient to cross-reference into that class all methods which result in the production of compounds which are insoluble in the electrolyte, even though their employment as pigments is not indicated, the analogy of the methods constituting a sufficient reason. The described methods which yield cyanogen, cyanogen halides, and other solvents for the precious metals should be cross-referenced from the present class into those which relate to the treatment of ores.

### Aqueous Bath, Organic Compounds, Oxidation Methods.
### Aqueous Bath, Organic Compounds, Reduction Methods.

In general, electrolytic methods which involve the transformation of organic compounds are distinctly anodic or cathodic, the electrolyte often having no other apparent function than to serve as a solvent or suspension medium for the compound undergoing reaction, and to furnish oxygen or hydrogen for its conversion; the material of the electrodes and the current density are the vital considerations. Certain reactions which are usually effected without a diaphragm, as the production of the halogen substitution compounds chloroform, bromoform and iodoform, are conveniently included under the broad class of "organic compounds," and thence cross-referenced into the class of haloids. For a closer subdivision of the abundant and rapidly accumulating references to the literature of the applications of electrolysis to organic chemistry the usual classification of the science may be followed.

### Aqueous Bath, Copper.

This sub-class excludes the great commercial application of electrolysis to the refining of the metal, but includes the plating methods. Copper is usually the metal involved when special forms, as tubes, wire-bars, etc., are to be produced by direct deposition, in the formation of stained glass windows or mosaics, in the electrolytic setting of bort or abrasives, and in similar applications classified under cathodes, but the use of the metal is so general that no useful purpose is served by cross-referencing these applications into the plating class. On the other hand this extended use has led to a correspondingly full study of the physical character of the deposits as related to the composition of the bath and the current conditions, the subject matter of the present class.

### Aqueous Bath, Gold.

This sub-class is restricted to the plating of the metal, the refining methods and the separation of the metal from its ores being referred to other titles. Even the precipitation of gold from its natural solutions, as in certain suggested methods for its separation from sea-water, is best classified under "Ores," these methods being, in fact, merely the usual ones employed for the treatment of solutions obtained by the action of appropriate solvents upon the ores with such modifications as are supposed to adapt them to the extreme dilution of the natural solutions.

### Aqueous Baths, Haloids.

This sub-class deals with the electrolysis of sodium chlorid and other haloid solutions, whatever be the products sought or the conditions of the work. It thus represents one of the most complex, interesting, and commercially important branches of electrochemistry. The sub-class might be subdivided along the structural lines, for those cells in which a septum, in the form of a porous diaphragm, a body of mercury, or a partial partition, is interposed between the chlorin and caustic compartments, are in general intended for the collection of caustic (or carbonated) alkali and chlorin, whereas the undivided cells are used for producing hypochlorites, chlorates, or perchlorates. Such a division of the class would, however, be somewhat misleading, for cells of each of the kinds mentioned have been described as suitable for each distinct purpose. It is advisable rather to segregate from the main title of haloids certain subordinate classes below referred to.

The residual class embraces (1) the theory of the decomposition, which, in this subject matter, bears an extremely intimate relation to the construction of the cell and the manner of operating it; (2) all cells and cathodes designed for the collection of chlorin or other halogen and caustic alkali or alkaline earth hydroxids, whether of the "diaphragm" or "gravity" type, excluding only those employing a cathode of mercury; (3) cells involving the use of soluble or non-polarizable anodes, whereby the chlorin is collected as a soluble or insoluble salt.

It is clear that a much closer subdivision of this general matter is feasible; thus it is common to distinguish between caustic cells of the diaphragm and gravity types. Experience has shown, however, that this is not advisable, for the reason that the whole trend of recent construction is to combine these types, utilizing the diaphragm, but separating the caustic therefrom by gravity. Furthermore, the very complexity of the reaction of decomposition, whereby every cell yields at least traces of every product, is an argument for unifying the subject matter.

### Aqueous Bath Haloids, Bleaching and Disinfecting Liquors.

These products are in general hypochlorites, hypochlorous acid, or solutions of chlorin, the last two being anode products and the first the result of the reaction between anode and cathode products. Accordingly the cells may or may not be compartmental, the latter type predominating. The conditions favor the series connection of the electrodes, and recent progress has been almost confined to devising means for increasing the efficiency of the cells by guarding against the leakage of the current through the electrolyte between the oppositely polarized faces of the intermediate electrodes. Aside from the materials used the cell constructions often closely resemble those used for the refining of metals.

### Aqueous Bath Haloids, Chlorates.

The cell constructions closely resemble those of the preceding sub class, the series arrangement being, however, less commonly applied. Recent interest has centered in the theory

of the reaction, and the observed effect of the addition to the solution of chromates and bichromates. Perchlorates are conveniently included in this sub-class.

Aqueous Bath Haloids, Mercury Cathode.

This sub-class is nearly coextensive with the electrolytic production of chlorin and caustic alkali by the aid of a cathode of mercury, the other grade industrial use of the mercury cathode being referred to "Aqueous Bath, Ores." Aside from the production of caustic, it is well, however, to include such work as that of Guntz and Féréé on amalgams, and the methods of Kellner and others for the reduction of nitrates, organic compounds, etc., the last being, of course, cross-referenced to its proper title.

Aqueous Bath Haloids, Treating Cathode Lyes.

It is intended to include here a range of interesting methods, the object of which is generally to overcome the backward diffusion on caustic by converting it into a less soluble compound, or by diverting the alkali metal to other uses than the decomposition of water; usually the compound formed is the carbonate or bicarbonate of the alkali metal. By extensions of these processes it has been proposed to obtain the most varied products, such as white lead, phosphates, soaps, rectified spirits, and even metals. The sub-class properly contains all methods wherein alkali metal is used for other purposes than the decomposition of water or the production of an amalgam.

Aqueous Bath, Iron.

An extensive and important literature deals with the deposition of the metal for industrial uses, as for the facing of electrotypes, and for the purpose of studying its magnetic properties, and its relations to carbon; its property of assuming the passive state under certain conditions has also been closely studied.

Aqueous Bath, Lead.

The cathodic deposition of the metal and its anodic separation as peroxid.

Nickel and Cobalt.

Both anode and cathode deposits are included. The records of the Patent Office show that during the interval between 1878 and 1880 nickel-plating was perhaps the most active of the electrochemical subjects of invention, but more recently attention has been given almost exclusively to the separation of the metal from copper and the production of heavy deposits of high purity.

Aqueous Bath, Ores.

The electrical treatment of ores generally involves the two distinct operations of solution and precipitation, the former being often, and the latter nearly always electrolytic. Electrolytic solution may involve the use of an ore or matte anode, or simply the preparation by electrolysis of such solvents as the oxyhaloid salts, the chlorid of cyanogen, etc. The precipitation may be a simple plating method; it may involve the use of mercury to receive the deposit, or, and most frequently, the precipitation may be accomplished by the employment of a properly chosen couple, no external source of current being used. So numerous and varied are the applications of this latter principle that it has proven advisable to establish the sub-class "Reduction by Couple" below referred to.

Aqueous Bath Ores, Gold and Silver, Cyanides.

The function of the current in the cyanid methods may be two-fold; it may directly or indirectly furnish the oxygen required by Elsner's equation, or it may accomplish the precipitation. In most cases the two are combined.

Aqueous Bath Ores, Gold and Silver, Halogens.

The chlorination methods often involve the use of electrolytic chlorin, the production of which relates to the sub-class of "Haloids." So far as concerns the present title, the current may yield chlorin in the bath containing the ore, or produce hypochlorites, hypobromites and similar solvents, or may effect the precipitation of the metals dissolved, the three operations being often combined.

Aqueous Bath Ores, Zinc.

The methods for the treatment of zinc ores are sufficiently distinctive to permit a separate classification.

Organic Non-Electrolytes in Plating.

The action of non-electrolytes under the influence of the current has its industrial applications, classified under the succeeding title, and under "Tanning." The present sub-class deals with the addition of non-electrolytes, in most cases colloids, to metal plating baths. The purposes sought are various, as the prevention of anode deposits of peroxid; the modification of the character of the cathode deposit; the modification of the physical character of the electrolyte, as in cases where it is desired that the evolved gas should be permitted to act upon an electrode; the prevention of oxidation of components of the electrolyte, etc.

Osmose.

The osmotic effect of the current in mechanically transporting water and non-electrolytes in solution has been applied to the extraction of moisture from wood and peat, and a variety of similar materials; to the extraction of sugar from comminuted cane or beets, and to the impregnation of wood by preservatives. In general, a permeable cathode is employed, the material itself often serving as the diaphragm.

Pickling.

In addition to strictly electrolytic pickling methods, in which a metal sheet to be cleaned is supported as an electrode in an appropriate bath, it is convenient to include under this title such chemical processes as are particularly adapted to the preparation of the plates for the deposition of metal.

(*To be concluded.*)

# PROF. F. HABER ON ELECTROCHEMISTRY IN THE UNITED STATES.—II.

(*Concluded from page 351.*)

In connection with the description of the Acker Process which Prof. Haber highly praises as noticed in our former article (Electrochemical Industry, 1903, June, p. 351), he gives a review of the various industrial processes used in this country for the electrolysis of sodium chloride. The Acker process is the only process in which fused salt is electrolyzed. A mercury cathode is used by the Castner Electrolytic Alkali Co. in Niagara Falls, according to the patents of Castner and Kellner (Electrochemical Industry, 1902, Sept., p. 12). These patents appear to cover the field so broadly that there is only one competitive undertaking in the same line; namely, by the Pennsylvania Salt Co., in Wyandotte, Mich., with the cell of G. and G. W. Bell, in which the mercury is said to be moved by an arrangement different from that in the Castner-Kellner process; the exit for the chlorine is alternately opened and closed, so that the chlorine alternately collects in the cell and escapes; while it collects in the cell, it pushes the mercury into a side chamber used for decomposi-

tion; when the chlorine escapes from the cell, the mercury, which has given off the sodium in the meanwhile, returns into the cell. The Rhodin process (Electrochemical Industry, 1902, Nov., p. 80) is briefly mentioned.

Diaphragm processes have come into extended use in this country. The diaphragm process of H. D. Dow has been in use for many years in the plant of the Dow Chemical Co., of Midland, Mich., The American Electrolytic Co. is completing a plant at Rock Glenn, near Buffalo, in which the Moore cell will be used, which is similar to that of Hargreaves. A greater number of paper and pulp mills, notably in the New England States, have installed in recent years their own electrolytic plants for making the bleaching liquid required in their mills; all of them use diaphragm processes. Dr. Haber compares their method of working with the process often used abroad of making hypochlorite in a cell without diaphragm and shows that this latter method would be less profitable under the conditions existing in this country; one of the main points is that very dilute bleaching liquid is unsuitable for pulp and paper mills, and that the production of strong hypochlorite solutions requires a comparatively very great consumption of power in cells without diaphragm; moreover the first cost of ordinary diaphragm cells is considerably less than that of the commercial hypochlorite apparatus. Dr. Haber thinks, however, that the hypochlorite apparatus should have a future in textile mills, for which purpose they have not yet been introduced in the United States; in this case more dilute solutions are required and the great simplicity of the operation of hypochlorite apparatus should be of importance.

Dr. Haber points out that the operation of diaphragm processes is much simpler than is generally supposed. For anodes Acheson graphite is mostly used, and in some cases platinum iridium. The diaphragm of asbestos paper or asbestos cloth is mostly supported by the iron screen cathode on which it is fixed; sometimes the asbestos paper is stiffened by covering it with a little cement by means of a brush. The electrolysis takes place in a hot solution (up to 80 degs. C.), the fresh electrolyte being continually supplied to the anodic room of the cell, so that the flow of the electrolyte is opposed to the passage of OH ions into the anodic department. The current efficiency depends not only on the details of the apparatus, but to a higher degree upon the degree to which the electrolysis is driven; the higher the percentage of sodium chloride, and the less the percentage of sodium hydroxide in the cathodic liquid, the better is the current efficiency. The proportion of hydroxide to sodium chloride in the liquid flowing out of the cathode department is mostly 2 to 3, sometimes 1 to 1, or even more; the current efficiency is under unfavorable conditions between 70 and 80 per cent, and under favorable conditions between 80 and 85, and may reach 90 per cent. With platinum iridium the e. m. f. per cell is 4.75 to 5 volts, with graphite electrodes 4.5 to 4.8 volts; the excellent durability of the Acheson graphite electrodes is pointed out.

The electrolytic production of chlorates is briefly referred to and a description is given of Darling's sodium process, which was in use on an experimental scale in the works of Harrison Bros. & Co., in Philadelphia. "As an experiment, Darling's undertaking was highly interesting, but the proof that the process is of commerical value, has not been brought during the time while it was in operation." It was Darling's intention to use the sodium for making cyanide; there were found to be difficulties in this direction. As sodium is of importance as starting point for the production of various valuable chemicals, Dr. Haber thinks that it is probable that Darling's experiment may be revived or that new suggestions may be made.

The two big plants founded by E. G. Acheson—the carborundum and graphite works at Niagara—are then taken up and characterized as "nearly the only important applications of electric resistance furnaces in the United States." A brief description of these two plants is given (Electrochemical Industry, 1902, Oct., pp. 50 and 52). Descriptions of the plants of the United Barium Co. (Electrochemical Industry, 1902, Sept., p. 16) and of the Electric Lead Reduction Co. (Electrochemical Industry, 1902, Sept., p. 18), and a longer discussion of the process of the Atmospheric Products Co. (Electrochemical Industry, 1902, Sept., p. 20), follow. Dr. Haber says: "In spite of the importance of this undertaking, I cannot deny that its status of development has disappointed me somewhat after the descriptions which I had read in the papers. I expected to find an industrial operation, and I found an experimental apparatus; true, it is of very great interest, but as far as I can see it is not possible to judge with safety what the commercial result will be." The fact that the Atmospheric Products Co. is to undertake the operation of the process on a large scale, allows to conclude that under the present conditions of the chemical market the commercial success of the process is considered to be assured. If experience shows that the wear and tear of the platinum-iridium electrodes is indeed negligible as it was found to be the case up to the present, Dr. Haber thinks that the commercial success depends only on the cost of the power and the cost of changing the dilute nitrogen oxide vapors into strong nitric acid. The cost of production of a mixture of calcium nitrite and calcium nitrate would be low, but such a mixture is not suitable for fertilizing purposes, because nitrites are poisonous to vegetables. The production of moderately concentrated nitric acid (up to 55 per cent $HNO_3$) from the dilute nitrogen oxide vapors and water, appears to be feasible, but he doubts whether in view of the large plant required, the cost of this operation is low enough if it is only an intermediate operation in order to make finally nitrates for fertilizing; he also doubts whether the percentage of nitrous acid can be made sufficiently small in this operation. On the other hand, an acid of 55 per cent $HNO_3$ is still without value for the industry of explosive materials, and the question arises whether the cost of changing it into highly concentrated acid would not consume the profit of the electrochemical process. "A complete new industry has not yet been founded. Nevertheless it cannot be denied that here a highly important step has been made, and great credit is due to the Atmospheric Products Co. for its activity."

Dr. Haber then discusses at length the copper refining industries of the United States; he gives data on the plants of the American Smelting Works in Maurer, N. J., the Baltimore Copper Rolling and Refining Co., and the Anaconda Electrolytic Copper Refinery, and compares at some length the relative advantages of the series and multiple systems of cells. In the latter all the anodes are metallically connected and the same is the case with the cathodes, while in the series system there are numerous intermediate copper plates between the terminal anode and the terminal cathode of a cell. The question which system is the better one, has not yet been decided. The most splendid new plant of recent years, that of the American Smelting Works in Maurer, uses the multiple system. On the other hand the Baltimore Copper Works which installed years ago a combined multiple and series system, have enlarged the series system (Hayden system) more and more while the multiple system is restricted to a small portion of the plant.

The adjoining Fig. 1 gives a view of a series cell, or rather of a six independent series cells, which are separated from one another by slate plates. In the first cell on the left hand all the intermediate bipolar electrodes are plotted, in the others they must be assumed to be present in exactly the same number. The motion of the electrolyte is indicated by arrows. The small rectangular plates, shown at the points where the electrolyte enters into the cells, represent pieces of glass against which the fresh electrolyte flows when entering the cell, so that proper circulation and distribution of the solution is accomplished.

The advantages of the series system over the multiple system are said to be the following: An enormous saving of floor space, less evaporation of electrolyte, less electrolyte, and less

power consumption. The disadvantages of the series system are: first, that it requires relatively very pure anode copper, while the copper anodes in the multiple systems may contain more silver and impurities before difficulties in the operation arise. The second disadvantage of the series system is that it requires more attendance, its operation being more complicated. Dr. Haber refers to a fact which is highly interesting from a theoretical point of view, that is the very good influence of a very small addition of a chloride (hydrochloric acid or sodium chloride) to the electrolyte upon the copper deposit; this addition prevents arsenic and antimony from being deposited together with the copper. Dr. Haber gives finally some data on the cost. He compares the actual costs at Anaconda with the costs estimated by Siemens & Halske for similar conditions as exist at Anaconda. With average wages for workingmen at Anaconda about three times greater than those assumed by Siemens & Halske, the actual cost of operation at Anaconda is three times less than in the calculation of Siemens & Halske. "This is the best proof of the high mechanical development of the refinery plants in the United States, which are admired by anybody who visits them. This also explains why the small refineries with an output of a few tons of copper per day cannot compete with the larger plants, and why the whole refining industry of the country is concentrated in a few large works, which, with an output of 100 tons per day, or more, are alone able to install such admirable mechanical apparatus."

Dr. Haber then discusses the problem of lead refining. Keith has been a pioneer in this field, and a new process of Betts is now worked at Trail, B. C. (Electrochemical Industry, 1902, Nov., p. 105). Dr. Haber sums up his description of the Betts process as follows: The most suitable method of treating the slimes has not yet been definitely determined. How far the cost of operation can be diminished when the process is worked at a large scale, is also uncertain. It seems doubtful whether for a raw material of lead, which is poor in bismuth or free of bismuth, the process can compete with the ordinary metallurgical refining process in plants with a daily output of several hundreds of tons, although the inventor calls attention to the fact that in his process there is no loss of silver, while such a loss is unavoidable in the metallurgical process. Whether the operation will be free of difficulties with a material of lead containing a great many impurities must still be considered as an open question. But the process, as it is developed at the present day, is without any doubt of considerable value for plants with a smaller output, and should be taken into special consideration in the case of lead containing bismuth.

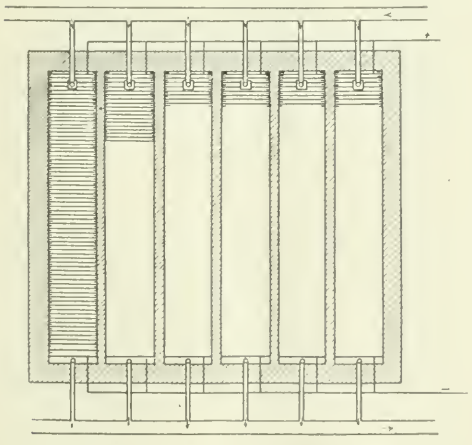

FIG. 1. DIAGRAM OF SERIES CELL.

The electrochemical treatment of copper-nickel matter is then taken up. On a commercial scale the problem has been solved in this country only once, by David H. Browne. The experiments of Hoepfner, Frasch and Ulke have not achieved commercial success, while Browne has produced for years in Cleveland daily 454 kg pure nickel and a corresponding amount of copper; when the Cleveland plant was closed in 1902 by the Nickel Trust, this was done in recognition of the fact that as an experimental installation it has proven in all points the commercial feasibility of the process, and with the intention to erect at a more suitable place a larger plant in which either the same process is to be used or a modification of it, which will be mentioned below, this modification being adapted to the change of the commercial situation caused by the formation of the trust. The industrial problem is the treatment of the nickel-copper ores of Sudbury in Canada. The ores generally contain 2 per cent of Ni and the same amount of Cu. In Canada the ore is roasted and melted with addition of limestone and coke. The resulting matte generally contains 20 to 25 per cent of copper, 18 to 23 per cent of nickel, 25 to 35 per cent of iron and 26 to 33 per cent of sulphur. This matte is further treated in converters and the resulting product which contains 35 to 40 per cent of Cu, 35 to 40 per cent of Ni and ½ to 1 per cent of iron, the balance being sulphur and a trace of silicon, is now being treated for the separation of the nickel from the copper.

This treatment has mostly been done in the United States by the Orford process, which is not an electrochemical process. The Canadian Copper Company years ago decided to develop a competitive electrochemical method, and this problem was successfully solved by D. H. Browne. Since the formation of the Nickel Trust the situation has been changed, as it now controls both the Orford process and the Browne process, and it seems that under the present condition the cost of the former is somewhat lower. But besides the simple separation of nickel from copper, there is another problem, that of the production of very pure nickel. The nickel made by the Orford process is sufficiently pure for use in steel manufacture and for nickel anodes for electroplating, while for certain other purposes a further refining is desirable. The electrolytic process of Browne gives at once a very pure nickel. The following tests of nickel are mentioned. Two tests of Orford nickel gave the following composition:

| Ni | Cu | Fe | C | S | Si |
|---|---|---|---|---|---|
| 98.91 | 0.13 | 0.40 | 0.23 | .... | 0.05 |
| 98.34 | 0.41 | 0.93 | .... | 0.078 | .... |

Cobalt is here included in the nickel. Some analysis of nickel, made by the Mond process, gave the following results, the first line referring to average samples, the second to very pure samples:

| Ni | Cu | S | Fe | Si | C |
|---|---|---|---|---|---|
| 98.32 | 0.064 | 0.058 | 0.513 | 0.034 | 0.014 |
| 99.34 | 0.014 | 0.007 | 0.225 | .... | 0.335 |

The electrolytic nickel made by the Browne process has the following composition (being the average of the products of three months):

| Ni | Fe | Cu |
|---|---|---|
| 99.85 | 0.085 | 0.014 |

The metal is free of arsenic, sulphur and silicon. This nickel is said to be even purer than the nickel anodes formerly made by the Balbach Co.

Browne found that in a hot nickel chloride solution, free of sulphates, the Acheson graphite anodes prove so excellent that their corners and edges remain sharp after two or three years; only if the solution contains sulphates, they are destroyed like other carbon anodes. The Balbach Co. gave up the manufacture of nickel anodes some years ago, because 50 per cent. of the anode weight remained as scrap and had to be remelted; this increased the cost of melting and manual labor to such a

degree that the process became commercially unsuccessful. Dr. Haber then gives a detailed description of the Browne process. As the process has not been described before to this extent, as far as we know, we give this part of Dr. Haber's address nearly in full. The description appears to be complete, with three exceptions: the concentration, the exact temperature and the current density are not given, as the inventor wants to keep these points secret.

The Browne process may best be explained with reference to the adjoining Fig. 2, in which high concentrations or large quantities are represented by heavy face type, dilute solutions and small quantities by light face type; final products are put in parentheses [ ], raw materials in parentheses ( ). The matte in crushed form (the diameter of the grains being 1 mm) is first brought into the calcination furnace, and by means of roasting it is freed from sulphur. In the adjoining melting furnace it is then reduced by means of charcoal, and a coherent, although not dense form; it is sufficiently adherent, but it is more crystalline than the copper of copper refineries. Between 2 and 2.25 grams are produced per ampere hour, while the theoretical value is 2.36 grams. A very small amount of $CuCl_2$ is sufficient to account for this difference with the theoretical value.

The proportion of nickel and copper in the fresh electrolyte applied to these cells is the same as in the anodes, as the electrolyte is made, as will be described later, from the nickel-copper shot, which in its chemical composition is identical with the anodes. The electrolyte is a mixture of $NiCl_2$, $Cu_2Cl_2$, NaCl and $FeCl_2$. When the electrolyte flows off from the copper cells, the proportion of nickel to copper in it is 80 to 1. The cathodes are removed from the cells after three or four weeks. The copper thus produced is not dense and of a very crystalline structure, but a single melting process is sufficient to change it into commercial metal. If any silver is in the anode

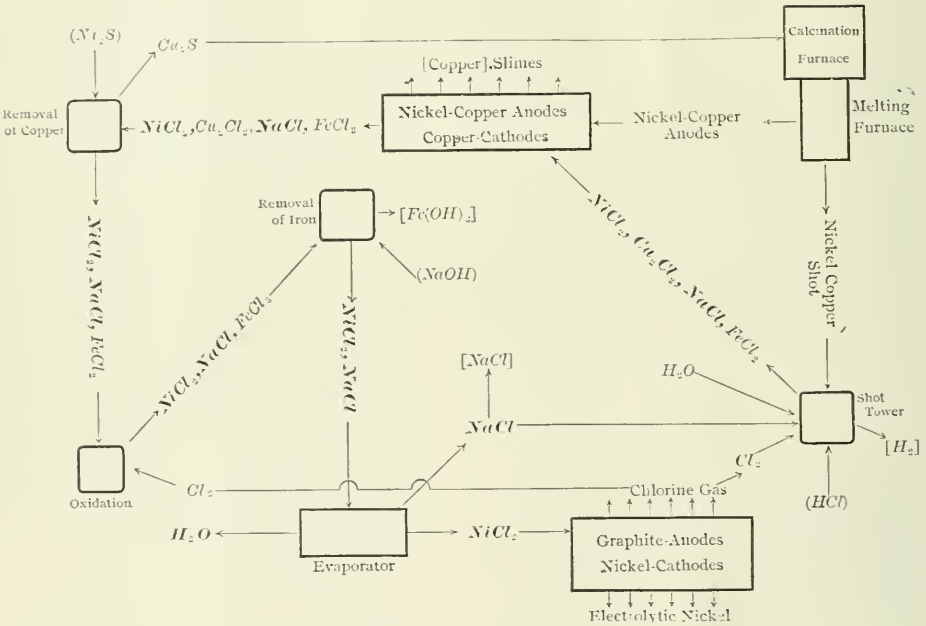


FIG. 2.—DIAGRAM OF BROWNE PROCESS.

one-half of the fused copper-nickel is poured into anode forms, the other half is poured into water, thus giving copper-nickel shot of a weight equal to that of the anodes. The anodes are placed in the nickel-copper bath; the copper-nickel in shot form is brought into the "shot tower." The composition is about Cu 54 per cent., Ni 43 per cent., the balance being iron and sulphur, the amount of iron present being generally below one per cent. In the shot tower the electrolyte for the copper depositing baths is made and flows continually over into these cells (or rather into a reservoir from which the cells receive their electrolyte). The ordinary multiple system is used. The anodes have a surface of 75 x 60 cm, and are 2.5 cm thick. Concrete tanks are used (see the description by D. H. Browne in Electrochemical Industry, 1903, April, p. 273); their dimensions are 256 cm length, 85 cm breadth, and 67.5 cm depth. Each tank has a capacity of 1.534 liters of the electrolyte. Circulation takes place by overflow from cell to cell; the cathodes are thin, electrolytically made sheets of copper. For 24 baths connected in series, the voltage is 6 to 10 volts, the current 500 amperes. At the cathode the copper is deposited in it passes completely over to the cathode, but the nickel copper matter is very poor in silver. The anode scrap is returned into the furnace. The anode slimes may be worked up to get the platinum metals, but this has not been done up to the present, as under the existing conditions such a treatment would not pay, and it was simpler to return the slimes to the furnace. The Sudbury ores contain in general a small amount of platinum metals; occasionally, however, rich samples are found, containing Pt $As_2$; very rich sands are also occasionally found, for instance in the Vermillion mine a sand containing 300 grams of platinum, 270 grams of palladium and 230 grams of silver per metric ton was found; it seems, however, that the rich ores or sands found are of small quantities, and that the large quantities of ores or sands found are not rich. To give an average figure for the percentage of platinum metals, the following composition is given by Ulke as the average composition of Sudbury matte used by the Canadian Copper Co. in the beginning of 1902: 13.2 per cent. Cu, 17.8 per cent. Ni, 0.45 per cent. Co, 42 per cent. Fe, 21.4 per cent. S, and 65 grams Ag, 12 gr Pt and 12 gr Pd per 1000 kg.

To sum up the result of the first step of the Browne process, as described above, it is the electrolytic separation of nearly all the copper from the nickel; the remaining nickel, however, still contains 1 part of copper to 80 parts of nickel; these remaining 1.25 per cent. of copper are chemically separated from the nickel by treating the electrolyte which flows off from the copper cells with sodium sulphide and by filtering the cuprous sulphide off. The solution which is now a mixture of $NiCl_2$ NaCl, and a small amount of $Fe\,Cl_2$ is then treated with some chlorine gas (which comes from the nickel cells as will be described below) in order to oxidize the ferrous chloride to ferric chloride. By means of sodium hydroxide the iron is then removed from the solution; after removal of the ferric hydroxide, the solution is a mixture of Ni $Cl_2$ and Na Cl and is then brought into the evaporator. This evaporator was described in Electrochemical Industry, 1902, Nov., p. 62; it is shown in the adjoining Fig. 3, which shows the brick furnace which contains the oil burner at the right hand at D; a current of hot air is produced which enters the evaporator by a sleeve and leaves it at the left hand to the chimney. The solution is continually supplied to the evaporator through the short tube indicated at the left hand and flows off into the basin, F. By passing through the apparatus the solution is brought to such a concentration that the total sodium chloride separates out and is carried in suspension over B to F, where it settles down. The solution now contains only $NiCl_2$, and while still hot, it is passed to the nickel depositing cells; nickel is deposited on the cathodes and chlorine developed at the anodes. The solution which thus becomes more dilute is returned to the evaporator.

The nickel cells are made of concrete and the multiple system is used, as in the copper cells. They differ from the latter in the size and in the use of porous diaphragms. As the electrolyte has become more concentrated, the size of the cells

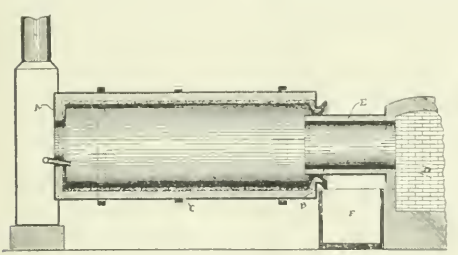

FIG. 3.—EVAPORATOR.

is 2.37 meters in length, 71.5 cm in breadth, and 30 cm in depth. The cathodes consist of strips of nickel of 38 cm length, and 14.7 cm breadth, several such strips being suspended side by side from a conducting rod across the cell. Opposite to each series of nickel cathodes there is provided a series of Acheson graphite anodes, each being surrounded by a porous clay cylinder, without bottom, the cross section being oval; the short axis of the ellipse (this axis is perpendicular to the surface of the electrode) is 8.75 cm long, the long axis 16.25 cm. These clay cylinders reach nearly to the bottom of the cells, although some space is left between their lower ends and the bottom, in order to make a free circulation of the electrolyte possible. These porous diaphragms prevent successfully any chlorine from passing to the cathodes and diminishing the current efficiency. The efficiency is therefore very good; during a period in which 10,000 kg of nickel were produced it was in the average 1.020 gr Ni per ampere hour, i. e., 93.5 per cent. of the theoretical current efficiency. The upper ends of these cylindrical tubes are connected to a cross tube of pottery ware with an asphalt coating through which the chlorine is led off.

Nearly the total chlorine is led to the tower containing the nickel-copper shot; only a small portion is used for the change of $FeCl_2$ to $Fe\,Cl_3$. The consumption of power in the nickel depositing cells is much greater than in the copper depositing cells. The voltage at the terminals per nickel cell is 3.5 to 3.6 volts; there is also some loss of voltage in the conductors and contacts so that about 5.3 horse-power hours are required per kilogram of nickel deposited in the cells. This figure is deduced from the following dates representing a test of the operation in 1902. There were consumed during the test 52,524 horse-power hours; duration of experiment 679 hours; average current 896 amperes; total ampere hours 608,384;* number of cells during the greatest part of the time 16, and during a short period 15, the average being 15.97. As the cells were connected in series, the theoretical amount of nickel deposited would be equal to the product of the numbers of cells (15.97), the number of ampere hours (608,384) and the electrochemical equivalent of bivalent Ni in grams per ampere hour (1.09); this would give 10,590,000 grams, or 10,590 kg, while the amount of nickel actually deposited was 9,898.9 kg, or 93½ per cent. of the theoretical amount; the actual consumption of power was 5.3 horse-power hours per kg.

The difference of the power consumed in the deposition of the copper and the nickel is considerable. The weight of copper deposited from $Cu_2\,Cl_2$ per ampere hour is about twice that of nickel deposited from $NiCl_2$ per ampere hour, while the actual voltage is twelve times smaller for the copper than for the nickel, hence the energy required for the deposition of copper in this process is twenty-four times smaller than for nickel for equal weights of deposits. The nickel deposited in the Browne process has excellent mechanical properties, while data concerning its remarkable chemical purity were given above.

In the tower which contains a quantity of copper nickel shot of the same weight as the anodes, the electrolyte for the process is produced; for this purpose chlorine is supplied from the nickel depositing cells and the sodium chloride from the evaporator; a proper quantity of water and a small quantity of hydrochloric acid is added; the shot is thus dissolved and the solution is supplied to the copper depositing cells as was described above. An addition of HCl is here necessary, because some additional chlorine is required for the formation of the electrolyte, while hydrogen escapes. This will become clearer from the following considerations.

For this purpose we may consider the additions to the solution during the different steps of the process. After the solution has passed out of the copper depositing cells, sodium sulphide is added, the sulphur combining with the copper of the cuprous chloride, while the sodium remains as sodium chloride in the solution. Later sodium hydroxide is added, the iron is precipitated as hydroxide, while new sodium chloride is formed in the electrolyte. Hence, in two steps of the process, sodium is substituted for the copper and the iron in their chloride solutions. If in the evaporator all the sodium chloride is separated from the solution its quantity will be somewhat greater than the amount of sodium chloride which was supplied to the shot during its solution in the beginning of the process. This surplus of NaCl comes from the Na, which was added in form of NaOH and $Na_2S$, and from the chlorine ions which were present, and as the chlorine undergoes a cyclic process partly free and partly in combination, it follows that there would be a deficiency in chlorine at the end of a cycle if a quantity HCl was not supplied to the shot, equivalent to the amount of Na in the added quantities of NaOH and $Na_2S$. These quantities are small because the amounts of $Cu_2Cl_2$ after the solution has left the copper depositing cells, and the amount of iron in the solution are small. Hence only a relatively small amount of hydrochloric acid is required.

The Browne process solves two problems. The one is the

* In Dr. Haber's report this figure is twice given as 60,831, but this is evidently a typographical error.

separation of copper and nickel in copper-nickel matte; the process may, therefore, be used as a substitute for the Orford process, and gives a considerably purer nickel than the latter does. The second problem solved will become clear, when we omit the copper depositing cells and the tower with the shot, and start with $NiCl_2$ with or without sodium chloride. This $NiCl_2$ would have to be produced from nickel sulphide or raw nickel metal in a special operation; then the process represents a method of electrochemically refining nickel, yielding as a by-product chlorine which would be changed to bleaching powder. The commercial situation in the United States and in Canada does not seem to be unfavorable to an application of the process in this form; there is no longer competition with the Orford process and there would be a market for the amount of bleaching powder. Suppose that the total nickel produced in the United States—about 4000 tons—would be produced electrochemically, then 5000 tons of chlorine or 14,000 tons of bleaching powder per year would be obtained as a by-product. In 1900 the import of bleaching powder into the United States amounted to 62,000 tons. Moreover there should be ready market for bleaching powder in the flourishing paper and pulp mill industry of Canada.

Dr. Haber then makes a general remark on electrometallurgical processes. The suggestions for industrial electrolysis of aqueous solutions are very numerous; the number of processes used in practice, however, is small. It is very often found that electrochemical methods are commercially too expensive compared with the older metallurgical methods. The reason of such failures is very often found to be an oversight of *the fundamental fact that the success of industrial electrolysis of aqueous solutions is mainly a question of maintaining the solutions pure during electrolysis.* We may express this in a somewhat exaggerated form by saying that everything can be accomplished with pure solutions, nothing with foul solutions. For the successful operation of the nickel process described the careful preparation of a pure nickel solution was of importance; for the Betts lead refining process it is of importance that the electrolyte dissolves impurities only to a very small degree. For copper refining the possibility of continually renewing the electrolyte is essential. It very often happens that a process which operated well with pure materials in the laboratory, failed at a large scale because the electrolyte became soon impure and its purification required cost and difficulties which had not been expected in advance. This point is generally more important than refined construction details of the apparatus. True, it is without any doubt of importance for an electrolytic process, if by a suitable arrangement of the apparatus some electric power may be saved. But the essential point which decides the suitability or unsuitability of a process for operation on a large scale is found in the chemical side of the problem, and the principal chemical problem is that the initially good electrolyte should be maintained pure with cheap chemical means and with as little labor as possible.

Dr. Haber then describes the manufacture of carbon bisulphide in the electric furnace, as operated by E. R. Taylor in Penn Yan, N. Y. (Electrochemical Industry, 1902, Oct., p. 60, 63, 76). The electric resistance furnace used there is said to be nicely and suitably arranged in many respects, while the operation is simple and effective. Finally some notes are given on the mining of sulphur by the Union Sulphur Co., by means of the pumping process of Herman Frasch, as operated in Louisiana.

Dr. Haber concludes his report by some general remarks. Neither in the United States, nor in Europe electrochemical industries arose from the science of physical chemistry, but after these industries have been built up, the advantages which a thorough training in physical chemistry may give to an electrochemical engineer, become more and more evident; hence the desire of the practical engineer to acquire and utilize theoretical knowledge; this desire is even more conspicuous in the United States than in Germany. While theory does not give in general the first impetus to new technical processes, yet it is the more useful by aiding the experimenter to review and understand the difficulties which are to be overcome and to save valuable time which, without theoretical knowledge, would be wasted in an absolutely useless desire to overcome existing laws of nature.

While the general chemical industry in the United States has grown up in connection with the older development in European countries, this is not the case with various electrochemical industries which were built up independently of European practice. True some electrochemical processes have been introduced to America from Europe, among them the Goldschmidt tin process, and the storage battery industry. Dr. Haber also counts the mercury cathode methods for electrolyzing brine among the processes imported to America from Europe. Although Hamilton Young Castner, the founder of this important industry, is an American, yet the mercury cathode process was invented after he had taken his residence in England, and his process achieved its great commercial importance first in Europe, after Castner and Kellner had become co-workers.

As the first of the great electrochemical industries which were developed in the United States, the aluminium industry is mentioned. It is the result of the work of Charles M. Hall, who, in 1886, found the proper electrolyte which is the essential foundation of the process. His invention was not a complete one in the first moment, as another important point had to be recognized, i. e., the necessity of avoiding external heating and of using the heat of the current for melting the bath. In the United States this point has never been looked upon as so important as it is considered to be abroad, and Hall has emphasized that it was a self-evident development to avoid external heating when larger cells were used, and the observation was made that the heat of the current alone at a moderate voltage was sufficient to keep the electrolyte in fused condition. Dr. Haber remarks that if this might be doubted, yet this second point of invention is also to be placed to the credit of an American, Charles S. Bradley. His internal heating patent and Hall's invention of the electrolyte give together a complete picture of the essential points of the aluminium process. References are made to the litigation between the Pittsburgh Reduction Co. and the Cowles Electric Smelting & Aluminium Co., and to the work of Héroult and Kiliani, who, independently, developed the aluminium industry in Europe.

Two other Americans, Eugene H. Cowles and Alfred H. Cowles, were the first to fully recognize the importance of electric resistance furnace operations for metallurgical practice. Some notes are quoted from the final court decision by which the novelty of the invention of the Cowles Brothers is recognized. The inventors themselves have not developed their invention on a very large scale, as their time was absorbed by patent litigations.

Others have built up the large electrochemical industries based on the application of the electric furnace methods. The most notable inventor in this line is Edward Goodrich Acheson, whose highly important work is represented by the industries of carborundum and of artificial graphite.

The series cell system in copper refining and the splendid development of the multiple system are also American accomplishments. The same is the case with the Acker process for electrolysis of sodium chloride, although the idea of using molten lead for absorbing the sodium was adopted from Europe. Finally the calcium carbide industry in which Thomas L. Willson was the pioneer was developed independently of European practice.

While America has thus achieved important successes independently and simultaneously, partly ahead of Europe, there are, on the other hand, other electrochemical industries in which Europe was or is ahead of America. The Griesheim (diaphragm) process for eletrolytically producing caustic alkali and chlorine was in successful operation when LeSueur

was still experimenting in Rumford Falls in Maine.* The sodium hypochlorite apparatus for textile mills, which exist in various suitable types in Germany and Austria, have not yet been introduced in the United States. There have not yet been developed in this country electrochemical industries of zinc or chromium salts, nor the electrochemical preparation of permanganates and of silicium and of organic compounds. Dr. Haber is surprised that carborundum has not yet found more applications in Europe; while diaphragm processes for electrolyzing brine are used to considerable extent in paper and pulp mills in the United States, this is not yet the case in Germany. On the other hand he remarks with surprise that ozone apparatus (ELECTROCHEMICAL INDUSTRY, 1903, Jan., p. 179) for sterilization of water have not yet been introduced in the United States where there should be a good field for them, in view of the fact that the drinking water in many American cities is very bad.

Dr. Haber recommends to carefully study the American electrochemical patents and suggests that visits from Germany to the United States for studying the commercial conditions in this country should be more numerous. He recommends especially that German manufacturers should be represented by fine exhibits at the St. Louis Exposition next year. This should be the case, especially in organic chemistry; he considers that the leading position of Germany in organic chemistry is based on the high development of scientific organic chemistry and the thorough scientific training of young chemists in Germany.

* Dr. Haber mentions in a foot note the "bell process" used in Aussig, which is a process without diaphragm, the anode and cathode solutions being automatically held separate by gravity. He remarks that this process apparently requires bells of small size, so that for an operation on a large scale many small apparatus would be required, which would, of course, be a disadvantage.

# CRITICAL NOTES ON DR. F. HABER'S REPORT ON ELECTROCHEMISTRY IN THE UNITED STATES.

## CHEMICAL EDUCATION IN THE UNITED STATES AND GERMANY.

By THEODORE WILLIAM RICHARDS.

Dr. Haber's report was highly interesting to me, and I am glad to say a word about his discussion of chemical education. On the whole, I agree with Dr. Haber's criticism, both favorable and unfavorable. That much time is lost in our college preparatory schools, and that this loss is due partly to the restless spirit of our nation, I cannot doubt. It must be granted, also, as Dr. Haber asserts, that too much of our teaching deals with knowledge as if it were complete, instead of in the process of growth. I quite agree with his praise of our methods of teaching elementary chemistry in the laboratory. I do not think that he makes it quite clear that the courses in chemistry which he quotes lead only to the degree of bachelor of science, and that the doctor's degree in America usually requires three years more of original work. Much of the work which forms a part of these scientific school undergraduate courses is counted toward the doctor's degree in Germany. The confusion caused by this difference in classification makes it a difficult problem to compare the value of the degrees in the two countries.

With Dr. Haber's unqualified opinion concerning the practical importance of physical chemistry I emphatically agree. Whether the present theories advanced by this branch of the science are transitory or permanent, it seems to me that knowledge both of its subject-matter and of its method is essential as well to the manufacturer as to the investigator in any branch of chemistry.

HARVARD UNIVERSITY.

## AMERICAN AND GERMAN UNIVERSITIES.

By Jos. W. RICHARDS.

In the technical part of Dr. Haber's paper I have noticed extraordinary assiduity in collecting facts, and clearness in stating them, so that the report forms, in this respect, one of the best general reports on the condition of the electrochemical industry in America which has ever been written. I note some places, however, where he has practised "the scientific use of the imagination," to fill up gaps in his information, and sometimes with results far from the truth.

In the discussion of our university and technical school instruction, Dr. Haber is usually correct in his statements, but his information is more fragmentary than concerning our electrochemical industry. He studied the later pretty thoroughly; the former, necessarily, only partially. His conclusions as to the low entrance requirements for our universities, and the low plane of undergraduate instruction given in them, may be true of those which he visited and describes, but is founded on too hasty and fragmentary a study of our universities and technical schools as a whole, to give much value to his generalizations, and really does grave injustice to some of our best institutions. I should say that it is impossible for even so keen an observer as Dr. Haber to give an entirely just opinion of our system of higher education as a whole, with less than six months' study of the subject here in America. Some of Dr. Haber's criticisms are true, some are only partially so; that is, they are true only of the institutions which he particularly chose for examination, and so do not apply unreservedly to all our universities.

After all, Dr. Haber would criticise us, as compared with Germany, for the relative absence of the deeper philosophical and theoretical studies and the preponderance of eminently practical subjects. On the other hand, we might reply by criticising the relative absence of the latter in the German universities. The golden, well-balanced mean between the two schools, between academic pedantry, on the one hand, and narrow commercialism, on the other, is the goal toward which our best institutions are tending, and toward which they are advancing more rapidly and more hopefully than the European universities.

LEHIGH UNIVERSITY.

## THE TEACHING OF PHYSICAL CHEMISTRY.

By ALEXANDER SMITH.

I have, indeed, little criticism to offer in regard to Dr. Haber's report. I agree in the main with almost everything he has said.

As regards the teaching of chemistry, and particularly the teaching of physical chemistry, I think the most important thing in the report is the part in which he draws attention to the difference between the old and the new chemistry. The instruction in chemistry, as it is given almost universally, both in Germany and in the United States, is strictly from the structural chemical standpoint. The composition of compounds and its expression in formulæ, the valency of elements, and the quantitative analytical methods of determining chemical proportions, are the things upon which most stress is laid. The real chemistry of the factory, of the laboratory, and of nature, on the other hand, is something enormously

broader than this. The study of physical chemistry is rapidly enlarging our knowledge of the conditions under which chemical changes occur, and consequently the results of physical chemistry cannot be excluded from any instruction in chemistry, from the most elementary to the most advanced. The illustrations which Dr. Haber gives, such as the manufacture of sulphur trioxide by the contact method, illustrate this. The materials to be used and the proportions, indeed, have long been known, but while chemical instruction of the prevailing kind regards these as the most important facts, it turns out that the labor and study required to determine the exact conditions under which this action may be carried out unfailingly and continuously, really represented by far the greater part of the task.

It is our duty to teach, not the chemistry of the past, but the chemistry of the present, and even, so far as may be possible, to anticipate the chemistry of the future, since our pupils are to form the chemists of the future. Whether, therefore, we teach formal physical chemistry or not, the results of physical chemistry and the spirit of physical chemistry must be indispensable features of modern instruction in every branch of the science.

University of Chicago.

## FIXATION OF NITROGEN FROM THE AIR.

By Charles S. Bradley,
President Atmospheric Products Co.

Dr. Haber's criticisms of the process of the Atmospheric Products Co. are, of course, largely correct. The Atmospheric Products Co. did not have a large plant in working operation at the time that Dr. Haber made his visit. We are trying to avoid the making of mistakes on a large scale, therefore we are operating single units until such time as we shall be absolutely certain that no changes are necessary. This method of developing new business is quite novel, as heretofore nearly every concern has been run into large operations at a too early date in order to avoid just such criticisms as these of Dr. Haber's; these criticisms tend to injure the commercial development, and therefore the inventor is always very anxious to reach the large manufacturing stage; this, however, should be approached with caution. Our capital being assured, it is not necessary that we should try in any manner to produce impressions on the public.

As to the platinum-iridium electrodes, platinum only is used, not iridium, and, as Dr. Haber says, "the experience has proved that the wear and tear is negligible," and we feel sure that there is no possibility of a greater rate of wear and tear during long periods of time than that heretofore observed.

As to the doubts that Dr. Haber expresses as to collection and conversion of the fumes into the various merchantable products, we would say that these are all provided for at a very low cost, and that the power is the principal item of expense in the operation; there is room, however, for a large profit after all expenses are paid.

Niagara Falls, N. Y.

## THE IMPORTANCE OF THE PURITY OF SOLUTIONS IN COMMERCIAL ELECTROCHEMISTRY.

By David H. Browne.

"Alles ist mit reinen, nichts mit unreinen Laugen zu erreichen." This generalization, by Dr. Haber, shows more than any minutiæ of detail his understanding of commercial electrometallurgy.

The difference between copper refining in the reverberatory and in the plating bath is not so great as appears on the surface. In the first case all the labor and cost is devoted to getting one percent of impurity volatilized or slagged off. Not till all the foreign elements are removed can any pure copper be obtained. In the other case all the labor and cost is spent in carrying over ninety-nine per cent. of the pure metal and the dropping of one per cent. impurity is simply an incident. Carry the copper-plating to such a point that some copper commences to plate in an impure state, and we are in exactly the same condition as the melter with his furnace full of blister copper; we can obtain no more pure metal till all the impurities are removed.

We have, it is true, the elective affinity of the current to aid us—just as in the Patterson or Parks process we have the crystallization of lead or the melting points of zinc alloys to aid us in the removal of silver. But just as the commercial importance of these processes depends upon our not pushing these selective tendencies of nature to their limit, so does the commercial importance of an electrical process depend on our keeping well within the selective tendencies of the electric current.

As Dr. Haber says, it is this neglect to keep initially good conditions permanently good which consigns so many promising processes to the scrap pile. Close experiment will almost always reveal the proper conditions under which certain work can be done—but the continuance of these conditions is attainable only by continual vigilance, which is as much the price of liberty as it is the price of success.

Copper Cliff, Ont., Can.

## THE "SERIES" VS. THE "MUTIPLE" SYSTEM IN ELECTROREFINING.

By Woolsey McA. Johnson.

It is with some diffidence that I approach this subject, for I have done but little work in this subject for some time. At present I am working out in an oil reverberatory furnace, so designed as to allow of a temperature constant to 10° C., the various conditions of temperature, rabbiling character of flame as shown by gas analysis for the common reactions of roasting, chloridizing, and smelting. This furnace will be described at another place. However, when engaged in the subject of the electrorefining of crude nickel I made a careful study of the question of the series and multiple systems, and will give below some of my conclusions.

For nickel refining the "series system" presented, to my mind at first, several manifest advantages, viz.:

(1) No "starting sheets" required.

(2) The "one-piece" electrode holds up the scrap, and reduces the percentage of scrap to below 20 per cent., as against 50 to 60 per cent. in the multiple systems.

(3) Connections are diminished, and high voltage used.

The advantages on experimenting did not prove to be what was at first expected, for I found that it was perfectly possible to make "starting sheets" cheaply on sheet iron cathodes. Strangely, Mr. Thum, Mr. Browne and myself independently came to the same conclusion, that the sheets should be annealed.

Next, Mr. Hybinette, superintendent of the Orford Copper Co., when I was in its employ, devised a cheap furnace treatment for the production of nickel anodes, of such composition that the scrap was reduced to a low figure (about 15 per cent.). Consequently I considered that the advantages of the series system for nickel refining were reduced to vanishing point.

Also, it is a fact that in the multiple system the anode is dissolved on both sides. Consequently, metal tied up in vats for same current density is double that of multiple system, and interest charge would be also double. On maturer reflection, looking at the question from the perspective of a year, it seems to me that there is very little to choose between the two systems for a nickel proposition.

This is just about the case with copper refining, and some collateral evidence proves it. At Baltimore the two systems are used side by side, the series for high grade, rich bullion that can be rolled, and the other for low-grade bullion that is not malleable. The fact that much less metal is tied up in the vats in copper refining (quite the contrary to the case in

nickel refining) cuts down interest charges. The cost of rolling, etc., balances the two systems.

The only other refinery that uses the "series" system has intimate commercial relations with another refinery that uses the "multiple" system. These relations are so close as to lead one to believe that profits are pooled, or that both are controlled by the same interests. These two refineries are both now in operation, as has been the case. Were there any great advantages of one system over the other, one refinery would be closed and remodeled. As a matter of fact, the plant using "multiple" system is being enlarged at the present time.

The above facts were pointed out to me by an extremely able metallurgist who is "en rapport" with the commercial conditions in the copper business. For plain and obvious reasons his name is not mentioned.

In my opinion the advantages of one system over another for either copper or nickel are just the advantages of measuring a length in centimeters or inches. The distance is the same whatever the unit be. A person would use that system of measuring to which he is accustomed. I believe, to meet the general conditions of copper refining, the "multiple" system to be the simpler and better.

HARTFORD, CONN.

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Besides the above articles, some shorter notes on various subjects of Dr. Haber's report were received:

MR. LAWRENCE ADDICKS, of the Raritan Copper Works, Perth Amboy, N. J., makes some remarks on the series versus multiple system in copper refining. He points out that "over 70 per cent. of the copper now refined in the United States is treated by the multiple system. The various refineries differ but little in the essentials of the process employed, the points of difference being in the methods of handling details. It is not so much what is done, as how it is done."

MR. LOREN R. VORCE, of Cleveland, Ohio, formerly with the Baltimore Copper Works, gives a note concerning the addition of a small quantity of salt (NaCl) to the electrolyte, which was introduced in the Baltimore plant several years ago. "I have always regarded its supposed beneficial results as more imaginary than real. This for two reasons. First, the Baltimore plant made, from the same anodes, and with the same electrolyte (practically), just as good copper before the practice was begun as it has ever made since. Second, I have made, myself, equally good copper without the use of NaCl."

MR. ANSON G. BETTS, of Lansingburgh, N. Y., states that he will read a paper on electrolytic lead refining before the American Institute of Mining Engineers, and that this paper will contain data that answer some of the criticisms made by Dr. Haber.

MR. HERBERT H. DOW, General Manager of the Dow Chemical Co., in Midland, Mich., states that they are unable to give any additional information on their plant, which is of peculiar interest for several reasons, as pointed out by Dr. Haber (ELECTROCHEMICAL INDUSTRY, June, p. 351). The plant has at the present time an annual capacity of about 20,000 tons of bleaching powder; they also manufacture the bulk of the bromides used in the United States, and other chemicals in a less extensive way. They are able to secure unlimited quantities of brine on their property, and coal is found within five miles from the plant.

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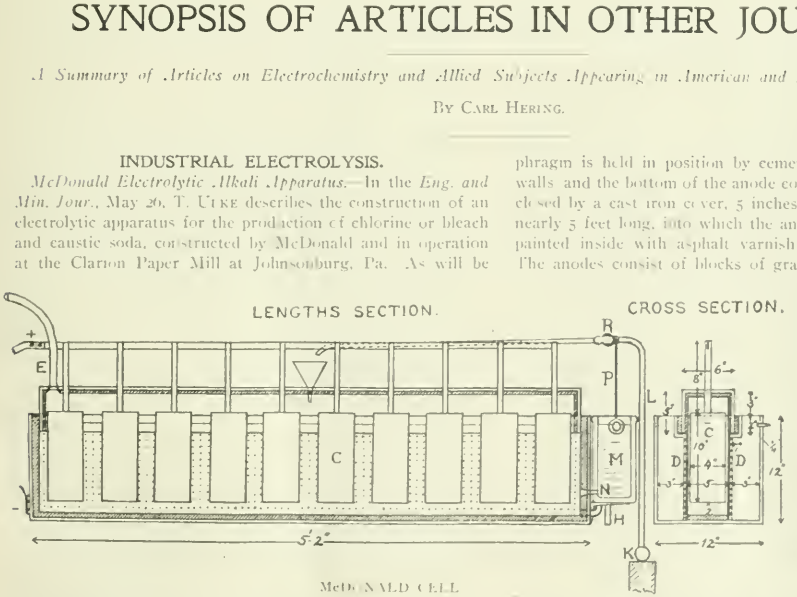
# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

BY CARL HERING.

## INDUSTRIAL ELECTROLYSIS.

*McDonald Electrolytic Alkali Apparatus.*—In the *Eng. and Min. Jour.*, May 20, T. UKE describes the construction of an electrolytic apparatus for the production of chlorine or bleach and caustic soda, constructed by McDonald and in operation at the Clarion Paper Mill at Johnsonburg, Pa. As will be seen from the adjoining cut, the cell consists of an iron tank, 1 foot wide and high, and 5 feet 2 inches long, which is cast in one piece, with two longitudinal partition walls, thus dividing it into three compartments. These partition walls are perforated, and against each perforated side wall of the central compartment, which forms that of the anode, there is stretched a diaphragm, consisting of a layer of asbestos paper fastened to asbestos cloth by a small quantity of sodium silicate. This diaphragm is held in position by cement, placed over both end walls and the bottom of the anode compartment. The latter is closed by a cast iron cover, 5 inches deep, 6 inches wide and nearly 5 feet long, into which the anodes are cemented. It is painted inside with asphalt varnish and lined with cement. The anodes consist of blocks of graphitised carbon, 4 inches square and 10 inches long, into each of which a copper rod is fastened by means of lead, to serve as connection for the current. The anodes are connected in multiple. The cathode is formed by the tank itself, or rather by the partition walls. The perforations in the partition walls are about one-thirty-second of an inch in diameter, and there are about 4 or 5 of them to the square inch. The partition walls are flanged, so as to form a seat for the reception of the cover, and for a layer of cement, which extends completely around the cover and hermetically seals the joints between it and the end and partition walls of the tank. A lead pipe leads from the anode chamber to a gas main of vitrified pipe, which carries the chlorine gas to absorbing towers, where it is brought into contact with lime water. Elbow pipes carry the caustic solution out of the cathode compartment. The brine is fed into the




McDONALD CELL.

anode compartment by an automatic feeder. It is stated that a plant has been in operation at the Clarion paper mill since the spring of 1902. The present installation consists of 50 McDonald cells, arranged in two parallel rows and occupying a floor space of about 60 by 15 feet. The author states that it appears that with a current of 420 amperes and 225 volts (4.5 volts per cell) there are 1400 pounds of chlorine produced daily. This figures out, according to him, to 167.5 electrical horse-power for 2.5 tons of bleach, or 67 horse-power per ton per day, or nearly 10.5 pounds of chlorine per horse-power day. Mr. McDonald, says the author, confirms that a ton of bleach does not cost him over $12 or $15 to produce, even without counting the value of the caustic liquor and hydrogen obtained as by-products. It is stated that the McDonald cell will be employed, as soon as the necessary equipment can be secured, by the Standard and Colorado City chlorination works in Colorado, which plants are said to have a combined daily capacity for heating 700 tons of gold ore, and are paying $45 per ton of bleach. This installation, says the author, according to report, will eventually comprise 500 cells, costing with royalty $50,000 complete, and located in a building approximately 200 by 200 feet. The caustic liquor from the cells is said, according to Mr. McDonald, to average 3 to 4 per cent. salt, and about 16 to 18 per cent. NaOH, and is wasted at present. Attention may be called in this connection to a patent by McDonald of an anode for electrolytic apparatus, which is described in Electrochemical Industry, Vol. I., p. 190. The anode proposed there is composed of strips of platinum, preferably 10 inches long and 2 inches wide, for an apparatus of the dimensions mentioned in the above article. According to the above it does not seem to be used, however.

*Electrolytic Production of Metals.*—H. A. Frasch, in the *Electroch. Zeitsch.*, for June, gives under this title what is virtually an extract from his patent, No. 720,235, of February 10, 1903, which was noted at some length and illustrated in the Analysis of Current Electrochemical Patents in the March number of Electrochemical Industry, p. 252.

*Electric Furnace Methods of Iron and Steel Production.*—John B. Kershaw begins a series of articles under this title in the issue of June 6 of the *Elec. Rev.* In the present issue the Conley, Héroult, Keller and Kjellin furnaces are described. This first installment does not seem to contain anything new.

*The Electric Furnace, Its Origin, Its Development and the Forms of Its Application.*—Under this title Adolphe Minet, the well-known inventor of the Minet aluminium process, and publisher of *L'Electrochemie*, begins in the June number of the *Electrochem. Zeitsch.* a series of articles. A number of illustrations of the various furnace constructions are given.

*Copper Ores.*—It seems from *Engineering*, May 1, that there is evidence that in Northern Rodesia and in Central Africa there is an enormous wealth of copper ore awaiting only the construction of a railway to be made readily available. It is believed that Africa will in a few years become the world's greatest source of supply of copper. Some reports of Farrell are quoted.

## THEORETICAL AND EXPERIMENTAL.

*Metallic Diaphragms.*—The question of metallic diaphragms is getting to be of considerable practical importance. Among the apparatus in which they are used, are that of Garuti for the manufacture of oxygen and hydrogen, and the Castner sodium apparatus, in the first of which a perforated sheet of iron is employed as diaphragm, and in the second a wire-gauze diaphragm. Buffa has proposed the following theory as far as Garuti's apparatus is concerned: "The perforated plate behaves like a diaphragm, if the tension of the electrodes is smaller than the double amount of the voltage of decomposition of the electrolyte. This theory is exact only when the metallic plate forms a complete dividing wall and separates the electrolyte into two parts, which do not communicate with each other." This statement is not very clear. The phenomena which appear with metallic diaphragms have been studied among others by Kaufmann, Danneel, Barillet and Brochet, the latter of whom, in an article in the *Zeitsch. f. Electrochemie*, gives some further experimental data on the subject. The apparatus used consisted of two ebonite frames, between which the platinum diaphragm plate was clamped. Two metallic plates which formed the sides of the apparatus, serve also as electrodes. The platinum electrode had a hole in the middle, and when the plate is acting as diaphragm, the current passes entirely through the hole. This takes place at a certain current density, while for lower current densities there is a certain equipotential circle, inside of which the plate acts as diaphragm, and outside as bipolar electrode. The diameter of the hole has, therefore, a decided influence on the result, but the form of the hole has no influence on the form of the equipotential line, except very close to the hole. If the plate has a certain number of holes, each of them behaves similarly, and to each belongs an equipotential circular line. The influence of the resistance of the electrolyte is similar to that of the current density. If the conductivity of the electrolyte is decreased, the equipotential circle becomes smaller. The author arrives at the following conclusions: The principal condition is that the material of which the diaphragm consists is not attacked by the electrolyte either before or after electrolysis; the plate will act the more perfectly as diaphragm; that is, will have the less inclination to take part in the reaction, the higher the voltage of decomposition of the electrolyte. Apart from this the good working of the diaphragm depends upon the following conditions: (1) Small diameter of the perforations; (2) the total surface of the perforations must be as large as possible relatively to the surface of the metal; that is, the perforations must be as numerous as possible; (3) small thickness of the plate; (4) good conductivity of the electrolyte. Finally, when the diaphragm is very thick, the resistance of the metal has to be considered. A part of the above article was also presented before the French Academy of Sciences, and abstracted in *L'Industrie Electrique*, May 25.

*Electrolytic Production of Persulphates.*—Though considerable work has been done in the matter of producing persulphates by electrolysis, not much is known about the question, to what extent different temperatures of the electrolyte influence the yield of persulphate obtainable. Data as to the influence of the material, of which the electrodes are composed, on the result of the electrolysis, were also very meagre. The appearance of a communication on this subject, by Levi, in the *Gazetta Chimica Italiana*, abstracted in the *Zeitsch. f. Electrochemie*, May 21, is therefore a welcome contribution to the literature on this subject. Ammonium sulphate was used as starting material and electrolysis was conducted with anodes of bright sheet platinum. The cathodes used in the different experiments were of platinum, nickel, lead and carbon, and the anode was always arranged between two equally distant cathodes. The electrolyte was kept weakly alkaline, and the cell was placed in a thermostat during the experiments bearing on the influence of the temperature. The interesting result was found that the yield of persulphate obtained was unchanged up to 30° C., and that it does not begin to fall off until 40° C. is reached. Up to now it has been considered quite essential that the electrolysis should be conducted at a low temperature, which is evidently disproved by the results obtained by Levi. The experiments with cathodes of different material showed that the lowest yield was obtained with lead, and the highest with carbon, though the differences were not considerable. The physical structure of the platinum anodes, however, had considerable influence on the result. Variations in the current density of not too great an extent were also shown to have no influence on the result.

*On the Electrolysis of Alkaline Sulphides.*—In *Comptes Rendus*, Vol. 136, Brochet and Ranson give their experiments on the electrolysis of alkaline sulphides. They confirmed the results of former investigators, that in dilute solutions of this kind the sulphide is transformed into sulphate. But if the

operation is carried out with a concentrated sulphide solution, heated to 50 to 70° C., the process is quite different. Then only sulphur is formed at the anode, while caustic soda and hydrogen appear at the cathode. The sulphur thus liberated dissolves in the concentrated sulphide solution to form polysulphides, and the colorless liquid becomes yellow. But as the solution tends to become richer in sulphur, the latter combines with the cathodic hydrogen and regenerates the sulphide. In this way the two inverse reactions are obtained, $Na_2S + 2H_2O \rightleftharpoons 2NaOH + H_2 + S$. The authors have also noticed a phenomenon previously described by Koelichen, namely, the oscillation of the needles of the volt and ampere meters, due to the deposition and successive solution of a minute layer of sulphur on the anode. Electrolysis was conducted by the authors with and without diaphragms.

*Electrolytic Reduction of Chlorate of Potassium.*—A note was recently presented to the French Academy of Sciences referring to recent experiments of Bancroft, Barrows and Brochet, and describing some earlier experiments made long ago by TOMMASI, in which he arrived at substantially the same results. If a solution of potassium chlorate, acidulated with sulphuric acid, is electrolyzed, there is obtained, according to the nature of the anode, an oxidation or reduction of the chlorate. With platinum electrodes there is a formation of perchlorate at the anode, without any trace of chloride at the cathode. If a platinum cathode and a zinc anode are used chloride of potassium is produced at the anode, but there is no reduction of the chlorate at the cathode. "The reduction of this compound in this case cannot be attributed to the hydrogen, but to the zinc, which on combining with the oxygen of the chlorate to form oxide of zinc, would reduce the chlorate to chloride." It is the same when chlorate of potash is reduced by zinc and dilute sulphuric acid, in which case the transformation of the chlorate into chloride is said to be due, not to nascent hydrogen, but to the combination of the zinc with the oxygen of the chlorate. If a solution of chlorate, not containing any sulphuric acid, is electrolyzed, a white precipitate of hydrate of zinc is obtained at the anode. The perchlorate of potassium treated under the same conditions as the chlorate, undergoes no reduction, even when a zinc anode is used. He also observed the reduction of potassium chlorate under the following conditions: If granulated zinc is introduced in a solution of copper sulphate containing this chlorate, the mixture, after a few minutes, becomes heated to such a degree that it soon boils, and the whole of the chlorate is transformed into chloride, while part of the copper passes into the condition of cuprous oxide. Chlorate of potassium is also reduced by the action of zinc on mercuric nitrate or nitrate of lead, by the action of tin or iron on copper sulphate, etc., but it is not reduced by sodium amalgam in neutral alkaline or acid solution. In the presence of dilute acetic acid, zinc does not reduce the chlorate, but the zinc-copper couple reduces it partially. The note is published in the *Journ. de l'Electrolyse*, May 15.

*Reduction by Means of Carbides.*—The question of what reaction takes place when metallic oxides and mixtures of metallic chlorides and oxides are reduced by calcium carbide, has been discussed at some length between Neumann and von Kuegelgen in the *Chemiker Zeitung* and the *Zeitschrift fur Electrochemie*. The former maintains that the reaction taking place is expressed by the equation, $M''Cl_2 + 2M''O + CaC_2 = 3M'' + CaCl_2 + 2CO$. In this case a primary formation of carbon monoxide would have taken place. Von Kuegelgen holds that the reaction takes place according to the equation $M''Cl_2 + 4M''O + CaC_2 = 5M'' + CaCl_2 + 2CO_2$, and that carbonic acid is the primary product. In order to strengthen his position VON KUEGELGEN publishes some further experiments on this point in the *Zeitschrift fur Electrochemie* of May 14. The experiments were conducted in an atmosphere of nitrogen, and the gases set free were aspirated and analyzed. The apparatus consisted of a tube of difficultly fusible glass, which was introduced into a combustion furnace. The mixture was contained in a tube of somewhat smaller diameter, which was introduced into the first, in order to prevent the destruction of the combination tube by the reacting substances. It was found, if a mixture was made of PbO and $PbCl_2$, according to the quantities $PbCl_2 + 4PbO + CaC_2$, that no CO was present in the escaping gases. If the mixture was made according to Neumann's proportions, $PbCl_2 + 2PbO + CaC_2$, up to 6.2 per cent. CO were found. A yield of 93.3 per cent. of metal was obtained with the first proportion. A mixture of $CuCl_2$ and CuO in the two above proportions gave up to 13 per cent. and up to 17.2 per cent. CO, respectively. No CO was found in the reduction of CuO alone. The formation of the above quantity of CO in the former case is explained by the very violent reaction which takes place. If the violence of the reaction is diminished by the addition of sand, the percentage of CO in the gases was cut down to 1.4 and 1.8 per cent. A mixture of $CuCl_2 + 4NiO + CaC_2$ gave 5.2 per cent. CO, while $CuCl_2 + 2SnO_2$ on the contrary showed up to 15.96 per cent. CO. Von Kuegelgen explains this latter by the fact that oxide of tin is much less reducible by carbon than the two other oxides, and that, therefore, more CO must be formed in spite of the lower temperature, $Cl_2 + 4CuO$ gave no CO. Von Kuegelgen concludes from these experiments that the combustion of the carbon in the oxychloride reduction depends on the one hand on the violence of the reaction which takes place in the reduction of the chloride by the calcium of the carbide, and on the other hand upon the easy or difficult reducibility of the oxide. The feebler a chloride acts, the more inclination there is to form carbonic acid with the easily reducible oxides; the stronger it acts, the less is this inclination. Only chloride of silver and chloride of copper, which act so much stronger than other chlorides, can occasion the formation of carbon monoxide, and the latter is not considerable, even with chloride of copper, which reacts stronger. By the addition of sand it was nearly completely suppressed. The more difficultly an oxide is reducible, the more inclination exists toward the formation of carbon monoxide. All this is claimed by von Kuegelgen, but these experiment with mixtures of the composition $PbCl_2 + 4PbO + CaC_2$, where he found no CO present, stand in direct opposition to Neumann's results in *Zeitsch. f. Electroch.* 8, 774, where the latter found 45.5 per cent. CO from a mixture in the same proportions.

*On Alkali Carbides.*—In a short article in the *Electrochem. Zeitsch.*, June, 1903, MOISSAN, after a short historical summary of the methods of carbide formation, describes the production of the carbides of rubidium and cæsium. If a wire of cæsium or rubidium is embedded in absolutely dry lamp black and the whole is heated in a vacuum tube, the combination of the metal with the carbon takes place when the temperature is slowly increased. After cooling there is found a small molten mass in the middle of the carbon, which, when brought into contact with water, produces a violent generation of acetylene gas; consequently carbide was formed, but it was not pure. The combination of the metals with the carbon was not complete, because a part of the carbide was decomposed on account of the heat set free in the reaction. It follows, therefore, that the production of the carbides of rubidium and cæsium will be more difficult than that of calcium or lithium carbides. These two carbides will decompose at a temperature which is much nearer to their temperature of production than is the case with the carbides of the alkaline earths. The carbides of rubidium and cæsium were, however, obtained by Moissan with the help of another method, namely, by starting from the ammonium compounds of the two metals. These new compounds are easily obtained by acting with liquid ammonia on the metals; thus the compounds $C_2Cs_2C_2H_2$ and $C_2Rb_2C_2H_2$ are formed. These crystallized compounds were then heated in a vacuum tube and the temperature was gradually increased, which resulted in the formation of the carbides.

*Electrochemical Reduction of m. Nitroacetophenone and m.*

*Nitrobenzophenone.*—In order to determine whether, and in what way the carbonyl group takes part in the reduction during the reduction of nitroketones, Elbs and Wogrinz subjected m. nitroacetophenone and m. nitrobenzophenone to electrolytic reduction in alkaline and acid solutions. The experiments are described in the *Zeitsch. f. Electrochem.*, May 21. A sheet of lead in sodium carbonate solution served as anode for the reduction of the m. nitroacetophenone in alkaline solution, and a nickel wire gauze of 1 sq. decimeter surface, as cathode. The results obtained show, that m. nitroacetophenone is easily reduced by the electrochemical method to m. azoacetophenone and to m. aminoacetophenone. The experiments on the production of m. azoxyacetophenone always furnished mixtures of the azoxy and the azocompound; the reduction to the hydrazocompound and its rearrangement to the corresponding benzidin did not succeed very well. M. nitrobenzophenone furnishes by electrochemical reduction m. azoxybenzophenone, m. azobenzophenone and m. aminobenzophenone, with very good yield. The hydrazocompound is very easily oxidizable and the benzidin, which is obtained from it, has properties which are unfavorable for its purification. A taking part of the carbonyl group in the reduction could not be proved in the various electrochemical methods which were used for the reduction of the nitro group.

*The Electrochemical Reduction of Various Stilbene Derivatives.*—In order to ascertain whether the well-known dye stuff "sun yellow" is in the main azoxystilbenedisulphonic acid, Elbs and Kremann subjected it to electrolytic reduction in alkaline and acid solution. For the experiments in alkaline solution the apparatus consisted of a tall beaker glass, with a porous cylinder as anode compartment, cold saturated caustic soda as anode solution, and an anode of lead, while the cathode was formed by a cylinder of nickel wire gauze. For the experiments in acid solution the anode liquid was 10 per cent. sulphuric acid. The following results were obtained. Sun yellow, p. azostilbenedisulphonic acid and also p. dinitrostilbenedisulphonic acid furnish in the electrochemical reduction in alkaline solution p. azotoluoldisulphonic acid as final product; the ethylene bond is broken and the azo group, which has been reduced to the hydrazo group, is reformed by the oxygen of the air. P. dinitrostilbene furnished by electrochemical reduction in alkaline solution p. azoxystilbene, in acid solution according to Bochringer's patent p. diaminostilbene. Under the same conditions p. dinitrodibenzyldisulphonic acid furnishes p. azodibenzyldisulphonic acid or p. diaminodibenzyldisulphonic acid. In the reduction of sun yellow, according to Bochringer's method there are obtained p. diaminostilbenedisulphonic acid and p. toluidenesulphonic acid; under the same conditions p. dinitrostilbenedisulphonic acid furnishes essentially only p. diaminostilbenesulphonic acid. The authors conclude from the results of these experiments that the dye stuff is essentially composed of p. azoxystilbenedisulphonic acid. Their researches are described in the *Zeitsch. f. Electrochem.*, May 14.

*Electrolytic Synthesis of Sugars.*—An account of experiments made by Walther on the electrolytic synthesis of sugars is given in the *Chemiker Zeitung*, 1902, Aug. 16 and Oct. 18, translated in *Engineering*, May 1. The chief interest lies in their great simplicity. He starts with carbonic acid, generated from marble and hydrochloric acid and passed through water. The current density being of great importance, he applies as anodes brushes of platinum wire 0.2 millimeter in diameter, the wire ends being all at equal distances from the cathode. The cathodes have a very large surface and are made of platinum, silver, mercury, iron, etc., and by preference of "clay, aluminium silicates." A red clay, containing some ferrous oxide, is mixed with the oxide $Fe_3O_4$, or with carbon, or with both, and the mass is smeared on iron wire gauze, yielding a cathode of high resistance. A clay pot serves as diaphragm, and the anode compartment is sometimes heated with the aid of a small incandescent lamp, so that the temperature of the anode solution remains about 5° C. higher than that of the cathode solution. The experiments were conducted in two parallel series: In the first, the solution of carbonic acid gas in water alone is used; in the second, certain salts, chiefly ammonium sulphate or phosphate, and also vegetable albuminoids, were added. The results did not differ in principle, although they depend much on circumstances. The electrolysis commences when the water is saturated with carbonic acid. The e. m. f. and current are gradually raised, by increasing the cathode surface, heating the anode compartment, and in other ways. Oxalic acid first makes its appearance; then tartaric acid is formed, and soon citric acid. When the general conditions favorable to the formation of citric acid are maintained and the current slowly raised, the appearance of carbohydrates is noticed: fruit sugar first, finally grape sugar. The sugars thus produced are optically active in the saccharimeter, although the rotary power was not quite so high as it ought to have been. Attention is called to the fact that the compounds produced become richer in carbon as the current and e. m. f. rise. Walther considers the phenomena essentially as oxidation and reduction processes, and it is pointed out that the electric current affords a very convenient means for bringing about certain reductions and oxidations which must proceed under that careful control which the regulation of current, e. m. f., concentration, temperature, etc., in the electrolytic cell enables one to maintain. "Electrolytic processes are more widely applied, especially in organic chemistry, probably, than is generally believed; chemical manufacturers are not very communicative." Some general remarks are added on the relations between electrochemistry and thermochemistry, and on the applicability of chemical ideas to life phenomena.

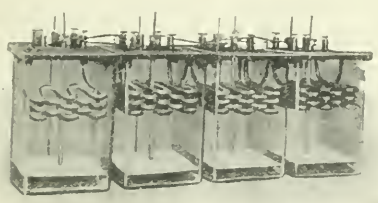
*Electrolysis of Potassium Silicate by Alternating Currents.*—Th. Gross in the *Electrochem. Zeitsch.* for June, gives the results of some experiments of the electrolysis of potassium silicate, dissolved in an aqueous solution or in a melt of potassium hydrate. An alternating current of 120 volts and 30 to 40 amperes was conducted through solutions of one part silica, two to four parts potassium hydrate and five parts of distilled water. The mixture was introduced into a silver dish, which served as one electrode. The other electrode was formed by a small silver crucible. Soon after closing the circuit the whole liquid colored brownish-black, and at the smaller electrode a moderate evolution of gas took place, which could be checked for a time by moving the electrode. Gradually there was a brownish-black body separated from the liquid. After continuing electrolysis for several hours, and introducting the resulting mass in much water, a greyish-black precipitate was obtained. The results obtained, according to the author, show that silicic acid disappears in the electrolysis by alternating current, and that instead of that a new body is obtained, which is not a compound of the ingredients of the materials used. When one part silica and five parts potassium hydrate were fused and electrolyzed in the same manner as above, a white flocculent body was obtained. In so far as the results said to be obtained are concerned, it must be said that a transmutation of elements, as is inferred in the above, would, indeed, be very surprising, and upset all our theories. As far as trustworthiness of results obtained by the author is concerned, it may be remembered that some years ago he came out in print, claiming that he had obtained by electrolysis a new element from sulphur, for which he proposed the name bythium. His experiments were repeated by Alexander, who gave exact quantitave figures, and were absolutely disproved. We will therefore do well to wait for some further proofs before we change our chemical theories.

*Crystallization in the Electric Field.*—Reasoning from the fact that a globe-shaped crystal body in a homogeneous electric field, if it has complete liberty motion, will tend to so arrange itself that the direction of the greatest dielectric constant coincides with the direction of the lines of force. Schmidt thought that if crystals would separate out in an electric field from a solution, they would assume a fixed direction. Experiment did not prove this supposition, but it was found that the crystals

only deposited at one electrode, while the other remained free. The substance used was sulphur, dissolved in a solution of carbon bisulphide. The electric field was maintained by an influence machine with about 40,000 volts difference of potential between two brass electrodes of 3 × 7.5 cm surface. A layer of sulphur crystals had formed on the anode at the end of the experiment, while the cathode had no deposit on it at all. For further details see *Phys. Zeitsch.*, June 1.

## PRIMARY AND SECONDARY BATTERIES.

*Electromotive Force of the Daniell Cell.*—Chaudier published in *Comptes Rendus* of last year a number of measurements on the Daniell cell, which apparently were in direct contradiction of the Nernst theory, in so far as he found a maximum of e. m. f. at a concentration of $\frac{1}{2}ZnSO_4 7H_2O$ in 100 grams water. The values obtained by him decreased from this maximum with increase in the $ZnSO_4$ concentration of the solution. The theory of Nernst would have required, however, that a decrease of e. m. f. should take place with increasing $ZnSO_4$ concentrations. As such a result as that obtained by Chaudier would have far-reaching significance on the theory of the subject, the experiments were repeated by COHEN and COMMELIN, and their results are published in the *Zeitsch. f. Electrochem.*, May 21. Their experiments were carried out with the greatest care, and with an apparatus so constructed that not the slightest diffusion of the copper solution to the zinc electrode could take place, as it influences the electromotive force of the system to a large degree. The authors proved first that a saturated zinc solution at 15° C. contains 150.65 grams $ZnSO_4 7H_2O$ to 100 grams of water, while Chaudier gives 200 grams. The difference is unexplained. The measurement of the e. m. f. shows that Chaudier's results were wrong, and that there is no contradiction between the actual experiments and the theoretical requirements, according to Nernst's equation. The e. m. f. decreases with the increase of concentration and a maximum at $\frac{1}{2}ZnSO_4 7H_2O$ does not exist.



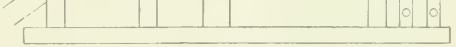
ELECTROLYTIC RECTIFIER.

*Oxydation and Reduction Potentials.*—SCHAUM and VON DER LINDE publish in the *Zeitsch. f. Electrochemie*, May 7, their results obtained in the measurement of electromotive forces with mixtures of various amounts of ferro and ferricyanide of potassium. The measurement was performed, according to the Poggendorff DuBois Reymond compensation method, with an Ostwald rheostat and a Lippmann capillary electrometer with vertical capillary. The average results agreed well with those calculated from the Helmholtz and Van't Hoff formulas. The authors also made measurements of potentials of mixtures of sodium sulphite and potassium sulphate, but do not give the results, as no definite conclusions could be drawn from them. Series of experiments which were conducted under exactly the same condition very often showed considerable deviations.

## GENERAL AND MISCELLANEOUS.

*Electrolytic Rectifiers.*—A new contribution to the subject of electrolytic rectifiers of alternating currents into continuous current is contained in an article by GRISSON in the *Electrotechnische Zeitschrift*, June 4. The author cast about for means to suppress the generation of hydrogen at the aluminium plate, which is used as electrode, as he had noticed that the destruction of the coating of alumina by hydrogen when the plate was acting as cathode was the main source of the breaking down of the apparatus. He solved this problem, in a physical way, by arranging a lead plate horizontally on the bottom of a glass vessel and fixing an aluminium plate parallel to it a short distance above, as shown in the accompanying illustration. When the aluminium plate now acts as a cathode, bubbles of hydrogen accumulate at the weak places, but these bubbles offer so much resistance to the current that only a small part of it passes through these damaged spots, and there is time for a new protecting layer of alumina to form beneath the gas bubble. There is also a cooling coil of lead pipe arranged in the upper part of the solution, in order to keep the electrolyte from getting hot. An average efficiency of over 60 per cent. was obtained. The formation of the protecting layer of alumina takes place best when a low current density is used.

*Interrupter for Conductivity Determinations.*—The Kohlrausch method for the determination of the conductivity of electrolytes depends, to a large extent, upon the proper working of the interrupter, which should require no further watching after it is once regulated, and it should be possible to change its frequency, if desired. A device, proposed by C. W. KANOLT, described in the *Zeitsch. f. Electrochemie*, May 14, is designed to overcome various difficulties met with in the operation of interrupters. It depends upon blowing a current of air from a small orifice against a small globe, secured to a wire which




INTERRUPTER.

is stretched between two points and the tension of which can be regulated in order to change the speed of vibration. It is shown in the accompanying illustration. A small platinum rod is fixed near the globe, which makes contact with a mercury receptacle, the height of which can also be varied. One terminal of the circuit, which is to be interrupted, is connected to the wire, and the other to the mercury. The interrupter is said to work well, if the air is blown against the globe with one-third to one-half atmosphere pressure.

*Wiesberg.*—A detailed illustrated description of the hydroelectric plant of Wiesberg, in Tyrol, is given by STOEGER in the *Elek. Zeit.*, May 14. The plant is situated near the place where the Trisanna and Rosanna Rivers combine to form the Sanna River. The plant is mainly destined to furnish electric power to the electrochemical works at Landeck. For the operation of the electric furnaces single-phase alternating current would have been best, but in view of the motor load, and of a prospective traction load, three-phase current at 40 periods per cycle was chosen. The alternators give three-phase currents at 12,000 volts, which is the voltage of transmission. Three 1,000 kw generators have been installed and there is space for three more. In the electrochemical works of Landeck, calcium carbide, pure silicon and silicon copper are made, and it is intended to also undertake other electrochemical work.

*The Development and the Present Status of Electrochemistry* is the title of a long, illustrated article, the first installment of which appears in the June number of the *Electrochem. Zeitsch.* The author is the editor of that journal, DR. NEUBURGER. The matter in the present issue is purely historical, leading from the very beginning of electrochemistry up to about the year 1800. This broad historical treatment is to be

the basis from which to arrive at an unbiased judgment, if the present method of investigation is on the right road to lead to an extension in breadth and in depth in the physical and electrochemical field. The author proposes to discuss that matter exhaustively. In view of Dr. Neuburger's well-known standpoint with regard to the present predominating school of physical and electrochemistry in Germany, it will be interesting to read what he has to say about the subject.

*Electrochemical Laboratory.*—A description of the equipment of the electrochemical laboratory of the University of Grenoble, France, is given in the course of a long, illustrated article by Barbillion in *L'Eclairage Electrique*, May 23. The equipment consists of a dynamo with separate excitation, giving 350 to 400 amperes at 7 volts. There is also a large storage battery which can give 2,500 amperes for various experiments and the testing of industrial apparatus.

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

Apparatus for the Electrolytic Production of Metals and Compounds.

*Apparatus for the Continuous Practice of Electrolytic Processes.* Pedro G. Salom, Philadelphia. Patent 727,457, May 5, 1903. Application filed September 17, 1902.

The invention relates to an apparatus by means of which, without interruption to the process, the material which is to be acted upon may be continuously supplied to an electrode, and also by means of which a product which is formed at an electrode may likewise be continuously removed. Though applicable to other processes, it is probably primarily intended for the carrying out of Mr. Salom's lead reduction process, as employed by the Electrolytic Lead Reduction Co., of Niagara Falls. As is well-known the process consists in the reduction of galena by hydrogen ions in the electrolysis of dilute sulphuric acid. Hydrogen sulphide is evolved at the cathode, and oxygen is set free at the anode. The apparatus is illustrated in the accompanying Fig. 1 in central vertical section. It is mounted on a wooden table A. The cell proper consists of an annular body B, of a trough-shaped cross section, with inner and outer peripheral walls *b b*. It is composed of antimonial

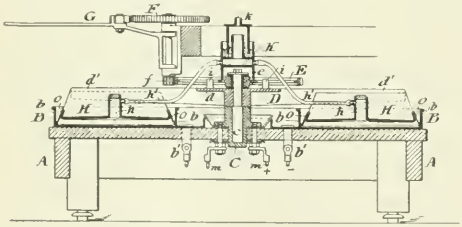


FIG. 1. APPARATUS FOR CONTINUOUS ELECTROLYSIS.

lead and is made a cathode by means of the connection *b' b'*. The anode consists of a series of segmental plates H, supported by the spider frame D, and bridging the spaces between seven of the eight arms of the spider frame, the space between the seventh and eighth arm being left open. Current connection to the anode is made through socket C and upright post *c*. The anode can be rotated by mechanical means, as shown in the figure. In order to prevent the escape of gases anywhere else but through the pipe *h*, both of the peripheral surfaces of the ring formed by the anode segments are provided with rubber petticoats *o o*, which sweep against opposite walls of the cell B. A box which is filled with the material to be acted upon is arranged in the open space between the spider frames above referred to, and is provided with a feeding slot, by which a continuous stream of material, the thickness of which can be varied, is fed to the bottom of the cell. A scraper-plate is also arranged, which, as the annular anode rotates, sweeps the spongy mass out of the apparatus. The process, according to the inventor, presents the following advantages: The galena may be spread very thinly and evenly over the cathode This results in very complete reduction. It makes possible the use of larger current densities—60 amperes per square foot of cathode surface—which hastens the reduction process. Being continuous, there is no loss of time contingent upon the removal of the electrodes in order to get at the product. There are no dangerous and injurious effects upon the workmen as are experienced when they have to handle and remove the electrodes.

*Electrolytic Apparatus.* F. J. Briggs, Everett, Mass. Patent 727,880, May 12, 1903. Application filed May 21, 1902.

The present invention has for one of its principal objects to accomplish decomposition of the salts of the alkaline metals, without loss of electrolytic action by reason of leakage or diffusion of the hydrate of the metal through the diaphragm into the anode compartment, and vice versa. This the inventor seeks to overcome by the use of two floating anode compartments, which he calls dialyzers. The apparatus is divided into two equal parts by an iron petition, which serves at the same time as auxiliary cathode. Each of the sections thus formed contains a floating anode compartment and a vertical cathode. The anode compartments are composed of frames, lined internally with a diaphragm, which consists of an outer sheet of perforated iron, an inner sheet of asbestos paper, and an intermediate sheet of asbestos cloth. A series of carbon anodes is arranged in the anode compartments. There is a complicated arrangement of pivoted levers, at one end of which is fastened the floating anode compartment of one section of the apparatus, while the cathode of the other section is supported by the other end of the lever, and vice versa. By this means the inventor claims to regulate the liquid in both compartments in such a manner that it will practically stay at an even height, after it once has been adjusted. The troubles incidental upon the diffusion of the anodic into the cathodic solution, or vice versa, if the level in one of the compartments falls too low, are thus stated to be obviated.

*Electrolytic Cell.* Hugh K. Moore, Lynn, Mass. Patent 728,274, May 19, 1903. Application filed August 29, 1901.

The application deals, not so much with an electrolytic cell, as with a method of fastening copper conductors into carbon anodes. In casting the end of the carbon into a lead backing, a difficulty has been found, in so far as the resistance of the cell increases gradually. This the inventor has found to be due to the porosity of the carbon, which permits the aqueous solution to work up by capillary attraction, and to form by precipitation a dry non-conducting layer between the carbon and the lead, thus greatly increasing the electrical resistance at that point. It is prevented by the following construction: The carbons, which have a low coefficient of expansion, are bored to form a socket for copper rods of a high coefficient of expansion. Between the copper and the carbon a bushing of a material of high conductivity is placed, which has a coefficient of expansion between that of copper and carbon, and is not affected by chlorine. Platinum, iridium, etc., may be used. The heat generated by the passage of the current, it is claimed, causes the expansion of the platinum into firm con-

tact with the carbon and similar contact of the copper with the platinum. This way of fastening may be all right, but would run up the expense tremendously on a practical scale.

*Cathode Holder.* Joseph Mathews, of Birmingham, and W. Davies, of County of Worcester, England. Patent 727,549. May 5, 1903. Application filed March 29, 1901. Divided April 21, 1902. Renewed March 5, 1903.

The patent refers to a cathode holder for electrolytic and similar purposes, especially for removing the tin from tin plate scrap. It consists of a cell, made of terra-cotta or porcelain, not affected by electrolytic action, which is open at the side and is provided with a trough-shaped receptacle at its lower end to catch whatever tin falls from the electrode.

*Electrolytic Separation of Copper and Nickel from Mattes or Ores.* E. A. Sjoestedt and J. H. James, of Sault Ste. Marie, Canada, assignors to F. H. Clergue. Patent 725,998, April 21, 1903. Application filed September 20, 1901.

The copper-nickel matte (preferably concentrated), or ore, is crushed to a powder and roasted. This is then treated with a 40 per cent. boiling hot sulphuric acid solution for eight to ten hours. This dissolves the iron, copper and nickel. The undissolved excess may be heated with fresh acid a second time. The liquor thus obtained is cooled and mixed with water, just sufficient to redissolve again the salts which have precipitated during cooling. This liquor is electrolyzed with copper cathodes and platinum, graphite or other insoluble anodes, in order to deposit the copper, starting with a current of normal density of 0.3 ampere per 100 square cm. of cathode surface. When the copper deposit begins to look dark and impure, the solution may be run off to treat fresh matte, since the acidity has decreased by the copper being deposited. Heat is applied as before, more of the matte is brought into solution, and the electrolysis and extraction is repeated as often as profitable. Finally, to deposit the copper in an adherent form, the current is gradually reduced as the deposit shows signs of becoming dark and loose. When no more copper can be deposited in a satisfactory form, the cathodic current density is reduced and electrolysis continued as long as any copper is deposited, or, if necessary, the last trace of copper may be removed by filtering the solution through a filter of nickel sulphide or iron sulphide. The electrolyte is kept agitated by a current of air during the electrolysis.

The copper having all been removed, the remaining liquor or solution is nearly neutralized with caustic soda, then made ammoniacal, the iron oxidized by a blast of air (preferably air rich in oxygen) and the precipitated ferric hydrate filtered off. The drawn-off liquor, being neutral or but slightly ammoniacal, is now subjected to an electric current of normal density of 0.6 to 0.9 ampere per 100 square cm. of cathode surface, nickel cathodes and graphitized carbon, or other insoluble anodes being used, the solution kept agitated by a current of air sufficiently heated to keep it at a temperature of 80° to 90° C., when the nickel is deposited.

*Apparatus for the Treatment of Gold or Other Ores.* W. B. McPherson, Los Angeles, Cal. Patent 725,804. April 21, 1903.

The apparatus consists of a series of tanks for treating the ores of the precious metals with cyanide solution, and to facilitate the action of the solvent by keeping the ore charges agitated. They are finally discharged into precipitation boxes where the solution is electrolyzed between iron anodes and copper cathodes. The arrangement and construction of the various boxes are described in detail. Means are also provided for keeping the level of the solution in the precipitation tank at a constant height by a float contained in a receptacle which is connected by a pipe with the precipitation tank, and actuates several valves in the bottom of the tank. No details as to the manner of carrying out electrolysis, current density, etc., are given.

*Production of Chromium Compounds and Alkalies.* H. Sweckteter, Griesheim-on-the Main, Germany, assignor to Chemische Fabrik Griesheim Electron, Frankfort-on-the Main. Patent 728,778, May 19, 1903. Application filed July 1, 1901.

The process consists essentially in subjecting the solution of one or more alkali metal salts to electrolysis, with an anode of chromium or a chromium alloy, or by using salts of chromium as an electrolyte with an insoluable anode, the anode electrolyte being separated from the cathode electrolyte by a diaphragm. Hydroxides or carbonates are added for the purpose of precipitating the alkali metal salt with the chromium and neutralizing the free acid which is formed with the chromic acid. For instance, with an electrolyte of sodium sulphate, an anode of ferrochromium (as obtained in the reduction of chrome iron ore by carbon) may be used; when electrolysis takes place with a diaphragm, after calcium carbonate or caustic lime has been added to the electrolyte, the following reactions take place: In the cathode compartment caustic soda is formed as usual. In the anode compartment free chromic acid, free sulphuric acid and ferric sulphate are formed, but undergo the following transformations:

(1) $2FeCr_2 + 9SO_4 = Fe_2(SO_4)_3 + 2Cr(SO_4)_3$.

(2) $Cr(SO_4)_3 + 4H_2O = H_2CrO_4 + 3H_2SO_4$.

(3) $H_2CrO_4 + H_2SO_4 + 2Ca(OH)_2 = CaCrO_4 + CaSO_4 + 2H_2O$.

(4) $Fe_2(SO_4)_3 + 3Ca(OH)_2 = Fe_2(OH)_6 + 3CaSO_4$.

(5) $CaCrO_4 + Na_2SO_4 = Na_2CrO_4 + CaSO_4$.

The impurities pass into the precipitate and are separated by filtration, while the sodium chromate remains in solution, which is evaporated to dryness or transformed by means of sulphuric acid into sodium bichromate. The operation is conducted as follows: Into the cathode compartment, containing an iron cathode, there is introduced a saturated solution of sodium sulphate, while a 25 per cent. solution of the same is put into the anode compartment, with a quantity of caustic lime sufficient to neutralize 100 grams of chromic acid per liter, and a corresponding quantity of iron. The anode is ferrochromium and the voltage is from $2^1/_2$ to 3 volts, with a current density of $1^1/_2$ to 2 amperes per square dm. When the concentration of chromic acid reaches about 100 gms. per liter, the solution is removed, the oxide of iron and the gypsum filtered off, and the solution evaporated to crystallize the sodium chromate. A solution of chromium sulphate or chrome-iron sulphate may be used as electrolyte, either neutral or acid.

*Oxidizing Organic Compounds.* Martin Moest, Hoechst-on-the Main, Germany, assignor to Farbwerke vormals Meister Lucius and Bruening. Patent 729,502, May 26, 1903. Application filed September 4, 1902. Divided March 11, 1903.

The inventor has found that cerium compounds under certain conditions are powerful oxidizing agents for organic substances. The ceric compounds are thereby converted into cerous compounds, but are at once reconverted by the current into ceric compounds. Exceedingly small quantities of cerium compounds need to be used. The process is illustrated as follows: (1) *Oxidation of Anthracene.*—A vessel lined with lead, serving as anode, contains sulphuric acid of about 20 per cent. strength, with preferably 2 per cent. of cerium sulphate dissolved in it. Any metal not attacked by the electrolyte may serve as cathode. The anthracene is introduced into the vessel while rapidly stirring, and the mixture is heated to about 70° to 90° C. Then the current is passed, which is maintained at a density up to 5 amperes per square dm., a tension of 2.9 to 3.5 volts being required. The current may vary within wide limits. Toward the end of the operation the temperature is raised to about 100° C. The process is complete, when the electrolyte keeps the yellow color of the unreduced ceric sulphate. The quinone thus obtained is filtered off, and the filtrate may be used for another operation. The yield of anthraquinone per ampere-hour is nearly quantitative, and the product obtained is of excellent quality. (2)

*Oxidation of Naphthalene.*—The finely ground naphthalene is introduced into an electrolyte composed as above and contained in a similar vessel. The temperature is maintained at 40° to 60° C., and the current density is about 1 to 2 amperes per square dm. As soon as the coulombs, corresponding to the quinone, have passed the electrolyte, the current is interrupted, and the quinone thus formed, containing still some unoxidized naphthalene, is filtered. The electrolyte contains also some phthalic acid. If phthalic acid is chiefly to be obtained, the operation has to be continued in proportion. (3) *Oxidation of phenanthrene.* In the manufacture of phenanthrenequinone the process is the same as for naphthalene. It is preferable to employ a somewhat more concentrated cerium sulphate solution. If the current quantity calculated to the quinone is employed, and the temperature maintained at about 50° to 60° C., then chiefly phenanthrenequinone is obtained. If the action of the current is contained, the oxidation leads, besides other products, finally to benzoic acid.

### Storage Batteries.

*Storage Battery.* F. A. Feldkamp, Newark, N. J. Patent 726,272. April 28, 1903. Application filed July 8, 1902.

The plate in this battery is constructed of a sheet of lead foil about 0.004 to 0.01 of an inch in thickness. It is provided with active material by impregnating or painting parchment, paper, linen, felt, asbestos, etc., with red lead or litharge, as the case may be, and folding it around the plate, the whole being then pressed out and ironed flat to secure the necessary contact. The fabric-covered plates are then placed under the needle of a sewing-machine, and the whole stitched well together, thus not only uniting them, but securing a number of perforations, serving for the circulation of the electrolyte. The plate is then dipped into a solution of diluted sulphuric acid and then cleansed in water, after which it is introduced into dilute ammonia water, the purpose being to render the fabric and the threads non-attackable by the acid of the battery. Between each pair of adjacent electrodes is placed a separator of light, inactive material, preferably of interwoven strands of cane. At both ends there is placed an insulating plate, and an aluminium plate on the outside of it. Stay bolts pass through holes left in the plates for this purpose, and the whole unit of electrodes can be tightly compressed by screwing up these tie bolts. This compact arrangement prevents any buckling of the parts and the disintegration which is due to jarring, especially when the cell is used for automobile purposes. The cell is illustrated in cross-section in Fig. 2, which, however, is out of proportion, the width being much increased and the length considerably decreased. Here 1 signifies the jar, 4, 4 the lead plates, 6, 6 the impregnated tissue, 14 are the separators, 15 the end insulating plates, and 17 the aluminium plates above referred to. The way of connecting the electrodes is clearly shown. The battery is primarily intended for automobile use, for which it consists of 23 to 30 of such electrodes, as described above, in a battery cell weighing about 10 pounds, and having the dimensions of 2⅝ x 6 x 11 inches.

*Secondary Battery.* P. Figuccia, Boston, Mass. Patent 726,274. April 28, 1903. Application filed May 22, 1902.

The invention relates more particularly to the means for retaining the active material in pasty or other form. The grid or frame of the electrode consists of a top and bottom bar, which are connected by a series of parallel juxtaposed bars These bars are made as double channels, so as to form long channels on opposite sides of the frame, into which the active material in pasty or pulverulent form is packed. Various modifications of this leading idea are described in the specification.

*Process of Forming Accumulator Electrodes.* G. J. Scott, Philadelphia. Patent 726,468. April 28, 1903. Application filed Feb. 28, 1903.

The forming process described by the author is said to consist in separating the accumulator electrodes during the forming operation by a current conducting baffle or partition, which is interposed between the electrodes in such a manner that it will enable electric current to pass directly from one electrode to the adjacent electrode through the current conducting baffle or partition, and will permit the electrolyte to pass from one electrode to the other, but will compel this passage of the electrolyte to be along devious or circuitous paths. The baffles are composed of carbon. The inventor states that it is important to have the baffle imperforate, as the utility of the process decreases very rapidly if the baffles employed in its execution are supplied with even small perforations.

*Reversible Galvanic Battery.* Thomas A. Edison, Llewellyn Park, N. J., assignor to Edison Storage Battery Co., Orange, N. J. Patent 727,117. May 5, 1903. Application filed October 3, 1902.

Mr. Edison states that his invention consists in the discovery that if an easily reducible metal like copper, mercury or silver is added to the iron or other active material in the make-up of an electrode for a reversible galvanic battery employing an alkaline electrolyte, better electrical contact between the particles of the active material is secured, so that the weight of active material will be reduced more than the

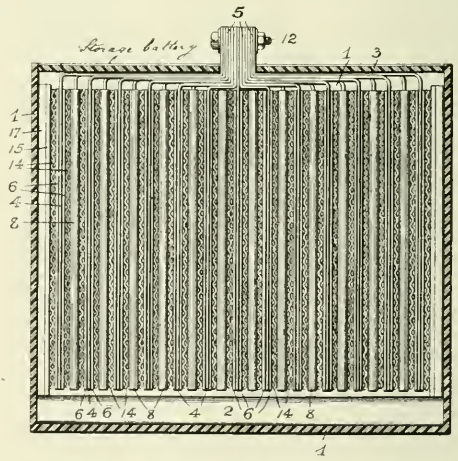



FIG. 2.—STORAGE BATTERY.

additional weight of the readily-reducible metal, while at the same time the cell will sustain a higher voltage through the entire period of discharge than would be the case if the readily reducible metal were not used. The preparation of the iron electrode takes place in the following manner: Finely divided oxide of iron is reduced by hydrogen, and when the temperature has been sufficiently reduced, water is forced into the retort to prevent the iron from oxidizing.. After the surplus water has drained off, the iron is mixed with sufficient ammoniated copper to produce as final result a mixture of 66 per cent. iron and 33 per cent. copper, although these proportions may be varied considerably. The addition of the copper compound is stated to result in the copper being converted to the metallic state and a portion of the iron becoming oxidized, while ammonia gas is liberated. The mixture thus obtained may be immediately molded into briquettes and used in the battery, but preferably about 20 per cent. of foliated or flake graphite is added in order to increase the coherence of the mass and its electrical conductivity, and to render its manipulation more easy. An electrode of the above description forms one electrode of the battery, while a mixture of nickel hydroxide and flake graphite constitutes the other. A mixture composed of finely divided iron, with 15 per cent. precipi-

tated oxide of mercury, to which about 20 per cent. of flake graphite have been added, may also be used in place of the mixture containing copper, described above.

*Plate for Electric Accumulators.* Donato Tommasi, Paris, France. Patent 727,496, May 5, 1903. Application filed August 3, 1901.

The essential feature of the plate consists in the employment of strips placed in close proximity to each other inside of a lead frame. The strips of each adjacent group are arranged at right angles to each other, one group being vertical, and the other horizontal. These strips serve to retain the active material. A diagonal conducting strip is provided on one face of the plate in order to insure a uniform distribution of the current through all parts of the plates. Free circulation of the electrolyte is provided for by having a hole in the central strip of each group. Various constructions embodying the above idea are shown in the specification.

*Storage Battery.* A. W. Charlton, Toronto, Canada. Patent 728,202, May 19, 1903. Application filed October 6, 1902.

The electrode of this battery consists of perforated lead tubes, rectangular in cross-section. A core of lead, having four wings, which extend into the four corners of the rectangular tube, and are likewise perforated, serves to retain the oxide of lead or other active material. The tube is elongated, that is, has one pair of faces considerably wider than the other pair; the active material is thus divided into triangular prisms. Separators are used to keep the electrodes apart. The inventor claims that this construction will prevent buckling of the plates, due to unequal expansion.

*Storage Battery.* Mary Emmé, New York. Patent 728,381, May 19, 1903. Application filed March 11, 1902.

This construction solves the storage battery problem in a wonderfully simple manner. "The positive and negative electrodes are put down in the ground, and "the earth between the electrodes belonging to each cell is moistened with a suitable (!) chemical preparation. A desired number of cells can be put down at suitable (!) distances in a piece of ground of suitable area. The cells thus constructed have the advantage of dispensing with vessels and insulating arrangements of ordinary storage batteries." It is a bitter reflection upon the sterner sex, that after so much of their brain power has been wasted in solving the storage battery question, a woman had to come and show them how to do it. Just think of the simplicity of going into the storage battery patch every morning and evening and sprinkle some electrolyte on the electrodes.

*Storage Battery.* J. C. Brocksmith, Chicago. Patent 728,667, May 19, 1903. Application filed January 14, 1902.

The invention consists in a storage battery, in which the grids comprise frames for supporting the active material and conducting rods embedded in the active material, and in which the plates formed of the grids and active material are spaced apart by washers made of insulating material, and being united by insulating rods passing through the plates and washers. The negative pole plate is only 75 to 80 per cent. of the thickness of the positive plate. The construction is described in detail.

*Separator for Storage Batteries.* E. D. Sperry, Cleveland, O. Patent 720,100, May 26, 1903. Application filed November 25, 1901.

The separator is formed of a sheet or plate of hard rubber, vulcanite or gutta percha, provided with suitable corrugations and perforations. The corrugations are formed in the plate while it is being vulcanized. This procedure is stated to overcome the tendency of such plates to straighten out again, when the corrugations were made by passing the heated plates through metal rollers. Staggered projections are also provided on the plate in order to keep it away from the adjacent battery element.

*Storage Battery.* Robert Darling, Rye, N. Y. Patent 729,140, May 26, 1903. Application filed December 26, 1901.

This invention relates to the class of storage batteries of the positive element resting on the bottom of the cell. It consists of an amalgamated zinc plate. The negative element consists of comparatively thick plates of antimonious lead, between which are a number of thin sheets of lead which are primarily corrugated, and then firmly pressed together. The laminated element thus formed is bound together by bolts, and has numerous perforations. A number of units similarly constructed are combined, in order to form a plate of the desired size.

### Galvanic Cells.

*Connector for Electrical Batteries.* W. R. Edwards, Weybridge, England. Patent 728,092, May 12, 1903. Application filed March 17, 1903.

The invention consists in an improved form of washer, interposed between the plates to be connected. It has projecting ridges upon both of its sides, which are forced against and into the plates.

*Battery Chute.* F. E. Paradis, Chicago. Patent 728,968, May 26, 1903. Application filed July 23, 1902.

This invention relates to improvements in storage receptacles for electrical batteries, especially when used underground. The objects of the invention are to provide a construction which protects the battery, so that it can be installed underground without danger of access of moisture or dirt, and to which access may be readily had without moving the receptacle. A mechanical construction is described in detail which embodies these features. Relief of any internal pressure is also provided for.

*Electric Battery.* E. Tweedy, New York; T. Roberts, Brooklyn; G. R. Tweedy, Danbury, Conn. Patent 729,240, May 26, 1903. Application filed May 22, 1900.

This invention relates to batteries of the type of double fluid cells, and is particularly applicable, though not limited, to that type in which use is made of a "non-porous" diaphragm, patented by one of the inventors. Such a diaphragm is made by filling the pores of an ordinary porous cup with a gelatinized mineral substance, such as silicate of soda. The present construction aims at overcoming some difficulties met with in the operation of those cells.

### Miscellaneous.

*Ozone Generator.* G. L. Curtis, New York. Patent 727,101, May 5, 1903. Application filed January 17, 1903.

This ozone generator is a portable device intended for therapeutical and similar purposes. It consists essentially of a glass tube open at both ends, an exhausted tube mounted within that tube and insulated from it, and a metallic connection on the exhausted tube in contact with a wire leading into the interior of the tube. The apparatus is intended to be unipolar, the body of the person who uses it serving as the opposite pole. The metallic connection is attached to a current of high potential.

*Apparatus for Purifying, Sterilizing or Ageing Liquids.* R. C. Turner, Columbus, O. Patent 725,803, April 21, 1903. Application filed May 20, 1902.

The apparatus comprises a number of vessels of non-conducting materials, situated below each other, so that the spout of each upper one can discharge into a metallic funnel which leads into the next lower one. The funnels are connected in parallel with one pole of the current, while pieces of metal, placed on the bottom of each vessel, serve as the other pole and are also connected in parallel. As the liquid flows into the first vessel, it closes the electric circuit from the funnel to the plate, and so on in the following vessels. In this way, the liquid as it flows down through the series of vessels in a small, continuous stream, is subjected successively to the action of electricity and air.

*Purifying Apparatus.* P. J. Boucher, Cleveland, O. Patent 728,440, May 19, 1903. Application filed October 16, 1902.

The apparatus consists of a metal pipe, lined on the inside with wood. Longitudinal grooves are cut into this lining, which support a series of aluminium plates, arranged horizontally and alternately in connection with the positive or nega-

the terminal of a source of electricity. The liquid to be purified, water, for example, is said to become purified by the electrolysis of the anode aluminium plates, which form a flocculent insoluble aluminium compound, thus causing the impurities suspended in the liquid to coagulate and deposit. Provision is made for the easy withdrawal of the electrodes when they require to be cleaned.

*Process of Treating Kaolin for the Production of Carborundum and Alumina.* F. C. Weber, Chicago. Patent 728,528, May 19, 1903. Application filed November 3, 1902.

The process consists in charging kaolin, having the formula $Al_2O_3 + 2SiO_2 - 2H_2O$, into a reverberatory furnaces, and at 300 driving off the non-combined and chemically combined water. This process leaves the kaolin in the form of a klinker as anhydrous aluminium silicate, which is then ground to a coarse powder. This is then mixed with coarsely powdered coke in atomic proportions, to produce, when the mixture is subjected to the temperature of the electric arc, aluminium carbide and carborundum according to the following reaction: $4(Al_2O_3 + 2SiO_2) + 21C = Al_4C_3 + 4SiC + 14CO$. The resulting solid mass is thrown into a tank containing water, where the aluminium carbide is decomposed according to the equation: $Al_4C_3 + 12H_2O = 3CH_4 + 2Al_2(OH)_6$, forming methane and aluminium hydrate. The resultant aluminium hydrate is separated from the crystalline carborundum by subjecting the material to a washing and filtering process, by which the aluminium hydrate is washed out. The liquid containing it is then evaporated to dryness and the aluminium hydrate heated again in a reverberatory furnace, to make it anhydrous, after which it is treated in the usual way, in order to produce metallic aluminium.

## CURRENT NOTES.

The Metallurgical Engineer in the Foundry.—In a paper presented at the recent Milwaukee meeting of the American Foundrymen's Association, Mr. Henry Souther, of Hartford, Conn., pointed out that a little money spent systematically for the services of a metallurgical engineer (not a chemist pure and simple) may save great sums. It is very much in the nature of an insurance against loss. Conditions may seem so favorable for months at a time possibly, materials may be received of such uniform and satisfactory quality, that money spent for expert services will appear to be wasted, and therefore the plan is discontinued. Then suddenly may be received shipments of coke or iron, which, had they entered the cupola, would have ruined at least one day's product before discovery, and the loss would have paid an expert for some time. This is not an imaginary occurrence, but a real one.

Mr. Souther excepts the chemist from this argument, for the following reason. A good chemist may be able to determine the amounts of the various elements in irons or fuels to the third decimal to the minimum limit of chemical error. He may be quick and do a large number of determinations per day. But of what use are results without practical interpretation and application? A chemist may become the best kind of a metallurgist, but only by personal contact with metallurgical operations in every detail and in several branches. A good share of common sense is a most valuable and necessary adjunct. A metallurgist need not be a chemist, but he must know how to use a chemist and the results obtained by the chemist. The chemist is an absolute necessity to the metallurgist. The steel industry is the most marked example of an industry thriving under the care of expert metallurgists assisted by chemists. The two are rarely united in one person, each being busy in his own field.

Rule of thumb methods gave way to exact methods about 1870 in the iron and steel industry to a marked degree. That which is common practice now would not be possible at all without the chemist to analyze under the direction of the metallurgist and with his interpretation of results.

It is no longer necessary for a foundry, large or small, to employ the exclusive services of a metallurgist. One may be found in nearly all the large manufacturing centers of the East or West, who is at the service of the general foundry trade on very reasonable terms. As a rule, these experts have their own chemical and physical laboratories; a necessity in nearly every problem under their investigation. One without the other is helpless. As a matter of fact, the chemist without that practical training and experience to which the author so strongly refers has blocked and retarded the advance of the use of expert knowledge into the foundry trade more than any one other element.

Every analysis the metallurgist should ask for ought to count in getting at results. A lot of good time and acid is wasted in determining the amount of graphite carbon in pig iron for cupola work. The total carbon is the only vital carbon result worth consideration in connection with iron to be used for melting.

The Faraday Society.—As was already briefly noticed in these columns, the newly-formed (British) Society of Electrochemists has adopted the name "*The Faraday Society*, to Promote the Study of Electrochemistry, Electrometallurgy, Chemical Physics, Metallography, and Kindred Subjects." The first ordinary meeting will be held on June 30. The proceedings of the Society will be published in *The Electro-Chemist and Metallurgist*. All papers presented to the Society will be printed and circulated among the members before being read, and, as a rule, they will be read in abstract only. Members and others unable to be present will be asked to send their contributions to the discussion in writing, and their remarks will be read out to the meeting. By this means it is hoped greatly to increase the value of the discussions, and to give absent members an opportunity of expressing their views. The Society shall consist of members and students, the subscription of each member being two pounds a year (about $10.00), and that of each student, one pound a year (about $5.00). Subscriptions are payable in advance on the first of January in each year. For the period from July 1 to December 31, 1903, the subscription is one pound (about $5.00) for each member. Members joining the Society before January 1, 1904, are exempt from paying an entrance fee. The Hon. Secretary of the Faraday Society is F. S. Spiers, 82 Victoria Street, London.

Mining in the Transvaal.—At the annual meeting of the General Mining & Finance Corporation, which owns a number of gold-mining properties in the Transvaal, held recently in Johannesburg, Mr. George Albu made some interesting statements on the re-establishment of the Rand mining industry after the war has been ended. Extensive repairs of machinery were necessary, but these have been undertaken with such an energy that nearly 95 per cent. of the mines which were working prior to the war, are now in a position to resume operation as soon as labor is obtainable. But great difficulties are involved in the solution of the labor question. The rate of progress now depends entirely on the supply of colored labor.

Hofman Medals.—The German Chemical Society has conferred its A. W. Hofman gold medals for this year to Prof. Henri Moissan and Sir William Ramsay.

A New Application of Electroplating.—A New York electroplating firm has recently introduced a new method of preparing wornout babies' shoes by electrodeposition. A heavy deposit of galvano bronze is first applied, and then there is plated on it either copper-bronze, oxidized silver, antique brass or gold; this preserves the shoes and turns them into a neat and original souvenir for the family, and an ornament for the curio cabinet. If the little toe is worn through and buttons are off or a seam ripped, they will look all the more natural.

Electrochemical Analysis.—The article of Mr. Ivar Juel Moltkehansen, in our June issue, contains two typographical

errors. On page 351 the second line from the bottom should read: It was found that the $PbO_2$ was more firmly deposited, etc. On page 352 the author refers to *Chemiker Zeitung*, Vol. 25, No. 37, not page 37.

## CORRESPONDENCE.

### ELECTROLYTIC CONDUCTION WITHOUT ELECTRODES.

To the Editor of Electrochemical Industry.

Sir: In your issue of June, page 343, bottom of second column, I noticed the statement that "This might give a method of measuring conductivity without the use of electrodes."

Exactly this method was used by Guthrie and Boys in 1880 to obviate the use of electrodes and the resulting polarization. If my recollection is correct, they rotated a magnetic cross within a chamber filled with the electrolyte to measure the resulting drag.

I regret that I cannot give you the exact reference.

New York City. William M. Grosvenor.

### ELECTRIC FURNACE PROCESSES FOR MAKING IRON AND STEEL.

To the Editor of Electrochemical Industry.

Sir: In your issue of May last, Mr. Ruthenberg did me the honor of criticising an article written by me and published in your issue of April last. The criticisms made have not seemed to me to be of importance, but I would be discourteous did I not reply. The production, as claimed, of 500 kilowatt hours at the cost of the consumption of 1,000 pounds of coal was denied by me under the following conditions, viz.: "Under *ordinary, continuous working conditions*" with coal "*burned under any kind of steam boiler.*"

I have been unable to read the article published in "*Power*, page 293," quoted by Mr. Ruthenberg, but I would at once submit that any test made after the manner such tests are usually made, would not fulfil the condition mentioned by me, viz.: *Ordinary continuous working.* Five hundred kilowatts are equal to 666 horse-power, 666 horse-power output from a generator (given an efficiency of 92 per cent.) requires the steam engine to indicate 724 horse-power. Such an engine consuming 1,000 pounds of coal would consume less than 1.40 pounds of coal per hour. Up to date this would be considered as being more than unusually good for *ordinary continuous working conditions* during *summer* and *winter.*

I will, however, state that were the cost of coal entirely eliminated from the calculation, a *good* water-power proposition, *properly* developed, could produce a *continuous* power more cheaply than can be done by the consumption of coal under a steam boiler and by the consequent use of steam, so made, in a steam engine.

I have little confidence in tests made by experts for the purpose of proving efficiency, unless such tests are backed up by proof, *obtained by actual work, under actual working conditions.*

As to the remainder the criticism, I can only regret that my English was not clear enough to enable Mr. Ruthenberg to grasp the point I, somewhat laboriously, endeavored to make.

That point was, that the commercial production of iron (viz.: pig iron, or iron in the condition in which it can be converted into steel,) from iron ores by the aid of an electric furnace, was not alone dependent upon the work of any one of the experts of the several different sciences involved, was not alone dependent upon the man who Mr. Ruthenberg designates as "selling steel," but that the commercial practicability of the process is dependent upon the existence of an average low cost of the several items which together make up the price, *paid by the consumer,* for the iron or steel delivered, and whether that cost be no greater, or whether it be less, than the consumer would pay for iron or steel of *equal quality,* when made by competing manufacturers, *using the old or any other process.* For myself, I do not care who or what he is, whether he be a scientist, who has given the commercial end careful and intelligent attention, or whether he be a plain commercial man, who has profited by the work and inventions of the experts, of any, or all, of the several sciences involved. *I argue, not to support men, but facts.*

I presume that Mr. Ruthenberg is willing to grant to the commercial man equal rights and privileges to those he claims for the expert scientist.

Ottawa, Canada. Louis Simpson.

### BATTERY PRACTICE AND THEORY.

To the Editor of Electrochemical Industry.

Sir: In your commentary on the pamphlet which we issued, and of which Mr. Fay was the author, you state that Mr. Fay's remarks on the chemistry of the storage battery are not up to date, and that it is not correct to say that the chemistry of the storage battery is by no means understood, and in justification of your criticisms you point to the extended investigations of Dolezalek. We think you have misunderstood Mr. Fay, as he does not by any means mean that the chemistry of the storage battery has not been considered thoroughly by chemists, or manufacturers, or inventors, but what he does mean is that the chemistry of the batteries is not understood by those who are engaged day by day in handling the batteries, and we think that a careful investigation will justify what Mr. Fay claimed.

In his book he cites cases and gives absolute experiences of his own to prove that what he says is so, and we, coming in contact with many charging stations, etc., have seen cases where the experience has been just as Mr. Fay states, that, owing to the entire absence of a knowledge of the chemistry of the storage battery, batteries have been allowed to be ruined. As Mr. Fay cites, there are instances where batteries have been charged under iron beams; where the acid, etc., has been allowed to come in close contact with impurities; where the electrolyte has been allowed to be kept in service too long; where electrolyte has been used that has been made from substances other than that called for by the manufacturer of batteries, and, indeed, we could name a hundred, if not a thousand, different instances which would prove conclusively that the chemistry of the battery was undoubtedly not known. This is what Mr. Fay means, and it is true.

Franklin H. Kalbfleisch Co.,
By P. S. Tilden, Vice President.

New York City.

## BOOK REVIEWS.

Elektro-Metallurgie des Nickels. By Dr. W. Borchers, Professor an der Kgl. Technischen Hochschule zu Aachen. Halle: W. Knapp. Price $0.55.

If we have any fault to find with this monograph it is with the excessive space devoted to practical methods used at the present time, and with the brevity with which the history of the subject is dismissed. Out of thirty-four pages, only fourteen are devoted to the pioneer patents to Berzelius of 1841, to Boettcher of 1843, to Bequerel of 1802 and to Adams of 1869. Hoepfner comes in for only three pages, which is remarkable, as in the Borchers' Electrometallurgy much more space is devoted to Hoepfner's demolishment. Poor Hoepfner is dead. Requiescat in pace. It was the writer's privilege to know him well: a brilliant man, eager, progressive, impetuous, impatient of the little details which were so often his undoing. Hoepfner was one of those daring pioneers who blazed a difficult trail ahead. If he wandered far in the forest, if he

stumbled often, let us who followed after, who found his ideas an inspiration, who put in practice what he saw in dreams and visions, let us be grateful for what he gave us. It had been a kindly act had Borchers given the praise that was Hoepfner's due.

But we digress. After discussing the patents of these men, after pulverizing the ideas of Strap, of Muenzing, of LeVerrier, of Frasch and Foerster, Dr. Borchers devotes forty-five lines to a description of the practical method of nickel-winning by fusion with alkaline sulphides. True, the details are all wrong, but as no details have been published since the Bartlett patents were issued ten years ago we can hardly blame Dr. Borchers for that. Forty-five lines given up to a process which makes only a million pounds of nickel a month is a graceful concession to the ignorant classes who want facts and not theories.

Coming down to present practice we find four or five pages devoted to a description of Ulke's process, which it is said is being installed by the Lake Superior Power Co., at Sault Ste. Marie. Through some unaccountable ignorance of the subject the Lake Superior Power Co. declare they do not know of having ever had any intention to install the same. Such lack of information is positively disgraceful. This news has been published time and again in the *Engineering and Mining Journal*, and has even appeared in Electrochemical Industry. Some one should really take the trouble to keep our manufacturers better posted.

To the work done in Dr. Borchers' laboratory by Dr. Guenther a scant fourteen pages are assigned. Guenther proposes to roast the nickel ores at a cost of from one to twenty pfennige, to smelt the roasted ore at a cost from 9 to 40 pfennige, and to concentrate this matte in converters at a cost from 6 to 15 pfennige per kilogram of metal. We cannot be too grateful for the accuracy with which the costs have been worked out. In order to separate copper from nickel in this matte he proposes to use the progressive method of Andre—patented in 1877—using copper sulphate as an electrolyte and obtaining nickel sulphate as an end product. This nickel sulphate is to be used as catholyte in a diaphragm cell with a lead anode in a solution of sodium chlorate. The resulting solution of lead is to be precipitated as lead chromate and sold as a pigment.

When we consider the simplicity of this idea and its innate superiority over the complicated scheme of Hoepfner's of splitting up nickel chloride into nickel and free chlorine, when we reflect that a two solution bath of this type is so easily constructed and that lead sulphate could by no possibility clog the pores of the diaphragm we wonder at the stupidity of our manufacturers in remaining oblivious to the many advantages of this process.

To those who can rise superior to the sordid considerations of commerce, who desire to know, not facts, but the elemental theories upon which all knowledge of the subject is based, the reviewer cannot too strongly recommend this pamphlet from the Royal Technical High School of Aachen. X. Y.

Laboratory Exercises with Primary and Storage Cells. By Karl E. Guthe, Ph. D. Ann Arbor, Mich.: George Wahr. 58 pages.

This small laboratory guide is intended to practically supplement the study of Carhart's "*Primary Batteries.*" The directions are very clear and elementary, and the exercises well arranged, and in this respect will undoubtedly be of considerable service to the author in his own laboratory class-work, and will be of assistance to others who wish to save the trouble of evolving their own laboratory schemes.

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The fall meeting of the American Electrochemical Society will be again held at Niagara Falls, from September 17 to 19. For the year 1904 it is intended to hold meetings at St. Louis, Mo., and Washington, D. C.

## ALTERNATING CURRENT RECORDING WATTMETERS.

The adjoining illustrations show the latest form (Model G) of magnetic suspension wattmeters for alternating current circuits, as made by the Stanley Instrument Co., Great Barrington, Mass.

The Model G, Stanley Magnetic Suspension Meter was offered first in the smaller capacities of 15 and 25 amperes; consistent, constant work in designing has obtained the result that meters in the Model G size and form are now manufactured, offered, and in use for both primary and secondary service from 110 volts to 12,000 volts, for capacities from 10 amperes to 10,000 amperes, and for frequencies from 25 to 133 cycles.

The Model G meter differs from its predecessor, the Model D meter, only in the size and weight. The Model G is but 9¼ inches long, 8¼ inches wide and 6 inches deep, and weighs only 17½ pounds.

Fig. 1 is a front view of the supporting frame, showing brake magnets, dial, etc.; Fig. 2 is a back view of the supporting frame, showing suspension magnets, rotating parts,

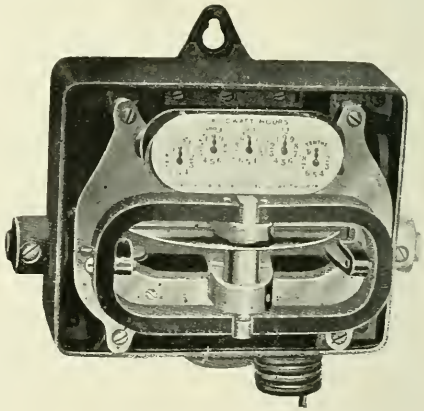


FIG. 1. STANLEY RECORDING WATTMETER.

dial and train connection; Fig. 3 shows the magnetic suspension elements and the rotating parts floated in air.

The magnetic suspension elements consist of the permanent magnet Y, and the steel plugs or pole bushings, A and B. The rotating parts floated in air are the aluminium disc and the soft steel vertical shaft, called suspension core, to which the disc is rigidly secured. The lower end of the suspension core is flanged larger, while the upper end is turned smaller in diameter than the body of the core.

The flanged lower end of the suspension core is in a cup formed in the lower pole bushing B; the upper end of the suspension core, when in magnetic suspension, is just inside of a recess in the upper pole bushing A. The difference in diameters between the flange of the suspension core and the cup in the lower pole bushing B, as also between the upper end of suspension core and the recess in the upper pole bushing A, is such that there is a predetermined space all around the flange in pole bushing B, and all around the upper end of core in pole bushing A.

When the suspension magnet is not in place the flanged end of the suspension core due to gravitation will naturally rest on the surface of the cup in pole bushing B, but, due to difference in diameters, it will not touch the circumference of the cup at any point, there being an air space between the periphery of the flange and the circumference of cup. When the suspension magnet is not in place and when the

lower end of suspension core rests on the surface of the cup in pole bushing B, the upper end of the core will be slightly below the lower edge of the upper pole bushing A.

Magnetism passes between the ends of the magnetized plugs (pole bushings A and B) attracts the steel suspension core, with the disc attached, in an upward direction, lifting the flanged lower end of the suspension core from contact with the surface of the cup in the lower pole bushing B and carries the upper end of the suspension core into the recess in the upper pole bushing A.

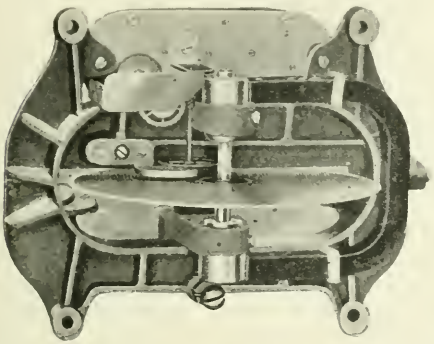


FIG. 2.—STANLEY RECORDING WATTMETER.

By the laws of magnetism, the magnetic field, into which the suspension core with its attached disc is thus attracted, acts uniformly upon the suspension core, holding the rotating parts in a predetermined definite position in space, free from mechanical support or contact of any kind. They float in air.

It is self-evident that in such construction there cannot be any friction due to mechanical rubbing contact. There cannot

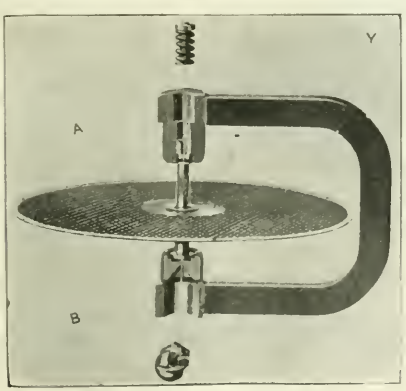



FIG. 3.—MAGNETIC SUSPENSION.

ever be any increase of friction due to such contact; consequently with magnetic suspension the original frictionless condition of the floated rotating parts must be permanent frictionless condition.

In meters having the bearings of the rotating parts in mechanical rubbing contact, friction and wear and increase of such friction and loss of energy is inevitable by reason of such rubbing contact. Polished diamonds, sapphires and other hard and precious stones and jewels, as well as polished hardened steel and metals, are all shaped and polished by the wear of rubbing contact. Wear means friction, and the greater the wear the greater the friction.

The second cause of great friction and of constant great increase of friction and loss of revenue from unrecorded consumed energy, necessarily inherent in meters having rotating parts in mechanical contact (that of the pounding effect of the alternating current on the bearings and shaft ends) is necessarily absent from the Stanley magnetic suspension watt meters.

It is manifest that, as the magnetically suspended rotating parts do not touch any other metallic or mineral parts, but simply float in the air without mechanical contact, it does not matter how violent may be the pounding or hammering effect of the alternating current, there can be no injury to the rotating parts or air bearings.

## OPENING OF THE EMPLOYEES' CLUB ROOMS AT THE WORKS OF THE WESTON ELECTRICAL INSTRUMENT CO., NEWARK, N. J.

On the evening of the 22d of May the directors of the Weston Electrical Instrument Co., Waverly Park, Newark, N. J., turned over to their employees the elegant club rooms recently constructed for them. The occasion was commemorated by a large inauguration reception and ball, to which each employee and a friend were invited, also a large number of the friends of the directors and all the prominent city officials of Newark, including the Mayor, also the Governor of the State.

Over a thousand guests and members of the club were in attendance and the affair was a success in every particular, and reflected a great credit on the various committees in charge. The club rooms throughout were decorated with masses of bunting, flowers and palms, with numerous incandescent lights festooned gracefully from column to column and hidden among the decorations.

A series of sketches by local talent began the evening entertainment. Following this Mr. Edward Weston, the president of the company, made a presentation address, in which he explained the roads along the employer and employee progress, and outlined the directors' ideas of how the interests of both could be best served. He pointed out that without complete understanding of each other's position no measure of successful co-operation could be obtained, and closed by asking for submission of ideas at any time which would tend to benefit the employees, assuring them that any plan presented that was at all feasible would have the company's earnest attention.

Mr. A. O. Benecke responded for the employees, thanking the company, and stated that the employees considered that a new era had dawned, in which their welfare was the predominant feature. In testimony of this, a huge loving cup was presented to Mr. Weston by the employees.

Mr. Weston in responding to the gift showed how greatly he appreciated the feeling of regard his employees extended toward him, and assured them that no business of the magnitude of the Weston Co. could achieve success without being able to repose confidence in every employee, and especially in the lieutenants of the business. He briefly reviewed this country's present prosperity, due to manufacturers, and touched on labor troubles and their disastrous effects.

The result of this employees club will be watched with interest by manufacturers generally, as its success seems assured.

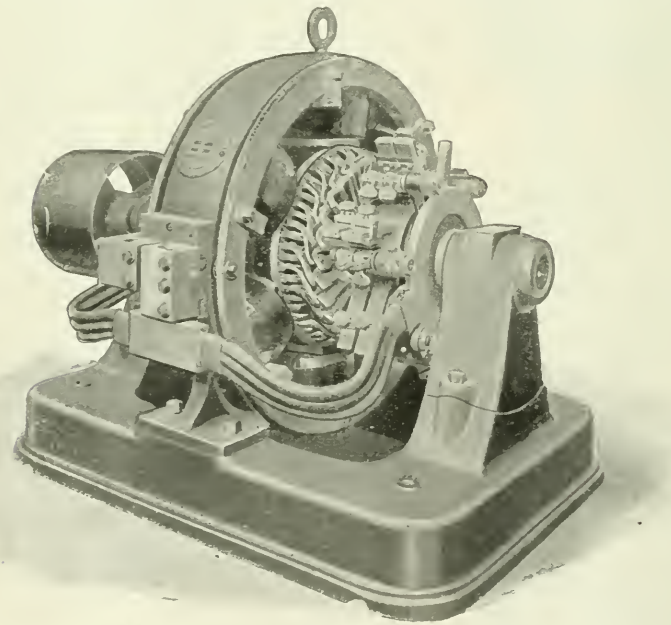
Before turning the apartments over to its employees the Weston Electrical Instrument Co. carefully considered every detail. They have placed the entire government, including the restaurant, in the employees' hands, and, moreover, given them all the furnishings and the benefit of the company's financial backing.

If any fault is found in any department the blame will be centered on the committee in charge, and in no manner can any trouble be construed into a company affair.

A feature of the restaurant is the foremen's dining-room, in which the president will dine with the heads of the various departments, and as all are seated at one large table, it is expected that any foreman will be able to discuss and obtain advice on any problem he desires. An ideal kitchen and ice manufacturing plant has also been installed, and there is a swimming tank over 130 feet long fitted up in the most sanitary fashion.

## NEW MULTI-POLAR DYNAMO.

The advantages of compound winding in multi-polar dynamo electric machines have been accomplished by the Hanson & Van Winkle Co., of Newark, N. J., in a most satisfactory manner, and this construction has been adopted on nearly all of their dynamo electric machines, maintaining the simplicity of construction and comparatively few parts that characterize their well-known bi-polar dynamos. The economy of weight by the



HANSON & VAN WINKLE COMPOUND MULTIPOLAR DYNAMO.

substitution of special steel for the field and other parts of these machines, and the absence of heat, owing to the perfect ventilation when running at their full-rated capacity, is all that may be desired.

The machines are self-exciting and will maintain full-rated capacity without variation from full load to no load. For use in operating a number of tanks in series they are especially adapted. This applies equally to a plating room where a number of tanks contain different solutions of varying densities, or a number of solutions require a difference in voltage for the successful production of work. When, for instance, a tank is emptied the voltage of the remaining tanks is not disturbed. The machine is automatically self-regulating. The Hanson & Van Winkle Co. are building these dynamos from 1,000 amperes, 5 to 10 volts, to any required size, enabling the operator to vary the voltage at will.

A careful test of one of the 2,000-ampere, 6-volt dynamos made by the Hanson & Van Winkle Co., and in use in a large New York establishment, gave the following results. The dimensions are: $30^{1}{}_{4}''$ wide, $40^{1}{}_{2}''$ long, $32^{1}{}_{8}''$ high. A working test at full load showed a commercial efficiency of 80 per cent., and an electrical efficiency of 93 per cent. The temperature rise over external atmosphere, after eight hours' run, was, for the armature, 40° F., for the commutator, 35° F.

## STERILIZATION OF WATER BY OZONE.

In various European cities the method of sterilizing water by ozone has been introduced on a commercial scale. In our issue of September, 1902 (page 31), we noticed the use of the Vosmaer-Lebret system in two waterworks in Holland, and in our January issue (page 179) we gave an illustrated description of the method of sterilizing water by ozone in use in two municipal waterworks in Germany; these two plants were installed by the Siemens & Halske Co., of Berlin. These large installations, which are operated in connection with waterworks for a whole town, are of more recent date. Smaller house installations for sterilizing the water used in a single household were installed several years ago by the Siemens & Halske Co. in Hamburg, during an epidemic of cholera morbus, and proved quite successful. That water may be sterilized by ozone to any degree desired, has been proven by very careful tests made by numerous physicians and bacteriologists. The only question — and one which can be definitely settled only by practice on a commercial scale —is that of the cost of the process.

The method of sterilization of water by ozone has not yet been introduced on any large scale in the United States, although there should be a promising field for such processes in our cities, provided the cost is not prohibitive. As is well known, the ozone is made from atmospheric air, by passing electric discharges through the air. The ozone process therefore belongs to the same general class of electrochemical processes of which the process of fixation of nitrogen from the air, used by the Atmospheric Products Co., is another, and probably the most famous, example.

We are informed that very recently a test was made by Mr. Otto, a Frenchman, at the plant of the Atmospheric Products Co. at Niagara Falls in the presence of officials of the Board of Health of various cities. In the ozonizing apparatus a voltage of 50,000 is said to have been applied (against 8,000 in the Siemens & Halske installation in Paderborn). The ozone thus produced was conducted through two pipes to the water-sterilizing tower, which is partly filled with rock, one pipe entering the tower at the top, the other at the bottom. The water, flowing through the sterilizing tower downwards, is purified by its contact with the two ozone streams. It is claimed that 30 to 40 horse-power are sufficient to sterilize 6,000 tons of water per day.

## PERSONAL.

Mr. David H. Browne, chief chemist of the Canadian Copper Co., is at present located at the New Brighton works of the Orford Copper Co.

Dr. Rossiter W. Raymond, the well-known secretary of the American Institute of Mining Engineers, has recently returned from a five-months' European trip.

Mr. Frank J. Buck, of Denver, Col., has been appointed consulting engineer for the San Miguel Copper Co., which will use Mr. Buck's electrolytic copper process.

Mr. E. M. Rogers, who for a number of years was manager of the Aspen Mine, Aspen, Col., and later manager of the Guggenheims' interests at the same place, has recently opened an office as a consulting mining engineer in New York City.

Dr. L. A. Parsons, of Johns Hopkins University, has been appointed assistant professor in physics at the University of Utah. At the recent New York meeting of the American Electrochemical Society Dr. Parsons presented a paper on ions and electrons.

Mr. Woolsey McA. Johnson, formerly electrometallurgist of the Orford Copper Co., is at present a consulting metallurgist. His headquarters are in Hartford, Conn. Mr. Johnson will either open an office in New York in the near future, or connect himself with a copper producer in the extreme West

Mr. A. B. Frenzel, of Denver, Col., who recently offered a prize to the American Electrochemical Society for the best research on rare metals, has just completed an investigation of the rare mineral resources of the San Juan Mountains in Colorado. He intends to visit now Arizona for the same purpose.

The marriage is announced of Prof. C. F. Burgess, of the University of Wisconsin, with Miss Ida Jackson, daughter of Mr. Charles H. Jackson, of Madison, Wis. Prof. Burgess has a host of friends among the electrochemical fraternity of this country, being known not only by leaders in the art from his work in the university, but to a larger public by his admirable papers and writings.

## UNIVERSITY NOTES.

Michigan College of Mines.—A bill has been passed by the Legislature of Michigan, appropriating $171,900 for the Michigan College of Mines at Houghton for the biennium beginning July 1 next. The most important item of this appropriation is that of $45,000 for the construction of a metallurgical laboratory. Electrometallurgy will receive special attention. It is intended to install furnaces of larger capacity than is usual in college laboratories. There is also an appropriation of $9,000 for extending the equipment of the department of mining engineering, which now occupies its new building erected last year, and an appropriation of $4,000 for completing the equipment of the chemistry building, also erected last year.

Columbia University has conferred the degree of Doctor of Science on Dr. J. J. Thomson, of Cambridge, and on Mr. Peter Cooper Hewitt, the inventor of the Cooper Hewitt lamp and rectifier.

University of Wisconsin.—We have received the catalogue of the University of Wisconsin for 1902-3. The total number of students was 2,870. There is a course in theoretical electrochemistry, with laboratory work in electrochemical measurements supplementing the lectures; also a course in thermal chemistry; a special laboratory course in physical chemistry; lectures on advanced physical chemistry; research work in physical chemistry; seminary in physical chemistry; all these courses are held by Prof. L. Kahlenberg. The course on applied electrochemistry and electrometallurgy, held by Prof. C. F. Burgess, comprises class-room and laboratory instruction in the laws, principles and theories involved in electrolytic phenomena; class-room and laboratory instruction in the industrial applications of electrochemistry; laboratory work; instruction in the electrolytic treatment of metal surfaces; instruction in chemical machinery and appliances. Bulletin No. 65 describes the summer school for artisans under the direction of the College of Engineering, the session beginning July 6 and ending August 14; among the subjects taught in the summer school are courses in electric batteries and in electroplating and electrotyping. In Bulletin No. 68 an illustrated description of the College of Mechanics and Engineering is given, with reviews of the different courses.

Worcester Polytechnic Institute.—The programme of the commencement week, 1903, was as follows: June 8 beginning of the entrance examinations; June 9, annual commencement lecture before the Washburn Engineering Society, given in the Electrical Engineering Lecture Room, Salisbury Laboratories, by Prof. H. B. Smith, on the "Relation of the Electrical Engineer to Modern Social and Industrial Progress," followed by the president's reception to the alumni and senior class. June 11, graduating exercises, commencement address by Superintendent O. H. Tittmann of the U. S. Coast and Geodetic Survey, on "The Work of the United States Coast and Geodetic Survey;" afterwards the alumni dinner, at the Institute, followed by the annual meeting of the Alumni Association.

## INDUSTRIAL NOTES

Mr. George T. Evanson, of Philadelphia, trading as George T. Eyanson & Co., has sold his interest in the manufacturing plant to The George T. Eyanson Co., Inc.

We have received from the Herbene Pharmacal Co. Scientific Laboratories, of New York (Mr. Alois von Isakovics, president), a catalogue of Twentieth Century Raw Materials for perfumers, soapmakers and manufacturers of toilet preparations, creams, etc. The catalogue contains an illustrated alphabetical wholesale price list of the various Herbene synthetic perfume materials.

The F. W. Braun Co., of Los Angeles, Cal., have sent us their catalogue of modern labor saving appliances for assayers and chemists. The pamphlet contains illustrated descriptions of a great many different types of crushers and pulverizers, ore samplers, hydrocarbon burners, crucible furnaces, melting furnaces, muffle furnaces, combination furnaces, coke, coal o charcoal furnaces, improved scorifier tongs, hydrocarbon blow pipe outfits, cupel machines. The various types of apparatus are illustrated.

The Westinghouse Electric & Manufacturing Co. have issued a neat and fully illustrated pamphlet on Electricity in Mining, which will be sent to any one interested in this subject, upon request. After some introductory on the economy of the use of electric power in mining and metallurgical plants, the applications to haulage, hoisting, driving pumps and air compressors, fans and blowers, drills and coal cutters, machine shop tools, etc. and to placer mining are discussed, and numerous machines and apparatus made by the Westinghouse Co for these purposes are illustrated.

## DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

*Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building Washington, D. C.*

Bleaching and Disinfecting Liquids.

*(Continued from page 368.)*

11,244. June 7, 1892. A. E. Woolf New York, N. Y.
Same as 471,454.

500,411. May 19, 1890. Carl Kellner, Vienna Austria Hungary.

Bleaches fibrous material by alternately subjecting it to the action of chlorine and an alkali, produced by electrolyzing an alkali chloride. The electrolytic cell has a cover with depending rils, between which hand the electrodes of alternate

polarity. These electrodes, of carbon, zinc or platinum, have an increased thickness below the ribs to bring their faces close together. The cell has a false bottom of foraminous or filtering material, through which the alkali is withdrawn to one of the bleaching tanks. The chlorine is forced into the second bleaching tank. Each of these tanks consists of three concentric vessels, with intermediate communicating spaces through which the solution is circulated. The tanks have bottoms of porous earthenware, to retain solid matter carried over by the chlorine, and filter outlets, to prevent fibrous material being carried back to the electrolytic cell. The electric current may be reversed in the cell, thus carrying chlorine to the alkali tank and vice versa.

565,706. August 11, 1896. B. S. Summers and C. O. Boring, Chicago, Illinois.

Removes the gum from ramie, jute, hemp, flax, etc., by placing them in the anode compartment of a cell having a diaphragm, the electrolyte consisting of a solution of sodium or potassium chloride or cryolite. The fibre may be supported on a perforated partition, above the platinum anode, or rest directly upon a flat horizontal anode. May immerse the fibre in caustic soda before placing in the cell.

569,173. October 13, 1896. H. R. Cassel, New York, N. Y.

Electrolyses a sodium chloride solution or sea water, and delivers the hypochlorite by a pipe system to places to be disinfected. May add water to dilute the product to the desired strength.

569,680. October 20, 1896. B. S. and L. L. Summers, Chicago, Illinois.

Similar to 565,706. Removes gum from ramie fibre, etc., by placing it in the anode compartment of an electrolytic cell having a diaphragm. Electrolyte, sodium hydrate containing sodium or potassium fluoride or cryolite. Fibre supported above or placed directly upon anode. May subject the ramie to the action of a sodium hydrate solution, containing a small amount of flouride, before treating it in the cell.

575,645. January 19, 1897. Eugene Hermite, Paris, France.

Electrolyzes a magnesium chloride solution, which may contain sodium chloride, or sea water. Cathode, a series of zinc discs cast in one piece with a horizontal shaft, strengthened by a central iron rod. Four anodes depend between each pair of cathodes. Each anode consists of a tube of platinum cloth, supported on a central non-conducting core, and sealed at the upper end into an insulating tube through which passes the conductor, a copper tube, the lower end of which is slotted and clamped on the upper end of the platinum. The electrolyte is delivered into the lower portion of the cell by a perforated pipe; the electrolyzed solution overflows into a gutter surrounding the upper edge of the cell.

579,236. March 23, 1897. Carl Kellner, Vienna, Austria-Hungary.

Bleaches a strip of cloth by passing it between feed rolls revolving in a tank containing a sodium chloride solution, thence between squeezing rolls, and finally into and out of the cell, beneath a revolving cylindrical anode. The cathode is a concave plate, beneath the anode. A perforated partition is interposed between the electrodes. First modification: A strip of cloth depends into the electrolyte between successive pairs of horizontal, parallel rollers, journaled above the vessel, the end ones serving as anode and cathode. The current follows the wetted cloth. Second modification: The strip of cloth passes between and in contact with horizontal, parallel conducting rollers, journaled above the vessel, each acting as a bipolar electrode; the wetted strip of cloth depends into the electrolyte, between successive groups of rollers. Third modification: Loose fibre is passed repeatedly between revolving cylindrical electrodes in the electrolytic cell, being returned from the bottom of the cell to a hopper above the electrodes by a conveyor.

580,919. April 20, 1897. A. E. Woolf, New York, N. Y.

Feeds sea water upward between alternate vertical anodes of platinum and cathodes of carbon and injects the product, through a perforated pipe, into a stream or sewer to be disinfected.

581,052. April 20, 1897. A. E. Woolf, New York, N. Y.

Passes a saline electrolyte upward between vertical platinum anodes and carbon cathodes. The product overflows into a tank which surrounds the cell and is delivered to a bleaching tank containing revolving arms. The spent bleaching liquor is withdrawn, strained and again electrolyzed.

589,959. July 6, 1897. Carl Kellner Vienna, Austria-Hungary.

Electrolyzes salt solutions in the bleaching vessel, which may be a rag engine. Bipolar electrodes of sheet copper, "tombac" or phosphor-bronze, coated on one side with platinum and on the other side with mercury; or of carbon. The electrodes may be covered with asbestos or glass-wool cloth, and are spaced apart by glass sleeves on hard rubber rods passing through the electrodes. May pass a strip of cloth successively between the electrodes and over and under rollers.

588,084. August 10,1897. G. H. Pond, Ashburnham, Mass.

Removes silica from straw by packing it in the cathode compartment of an electrolytic cell, a temporary grating being interposed between the straw and the cathode to facilitate packing. A central pipe extends through the packed straw and serves to withdraw the caustic soda from the lower part and again spray it upon the top of the straw, through a perforated distributor. Steam is introduced into the cell to raise the solution to the boiling point. The packing of the straw largely prevents chlorine from penetrating it.

588. August 10, 1897. G. H. Pond, Ashburnham, Mass.

Similar to 588,084. Straw is packed in a central compartment, separated from the anode and cathode compartments by removable gratings which are withdrawn after packing. Gates close passages between the central compartment and the anode and cathode compartments. The solution which is circulated through the straw may thus be either caustic soda, chlorine water or hypochlorite.

616,139. December 20, 1898. G. H. Pond, Ashburnham, Mass.

Cell has a vertical, concentric central chamber, with openings above and below through which the solution is circulated by a screw. Half fills cell with milk of lime, and then fills with sodium chloride solution. Pairs of carbon electrodes of opposite polarity are hung in the outer space.

616,988, January 3, 1899. B. S. Summers, Chicago, Illinois.

Removes gum from ramie and other fibres by first subjecting them to an alkali hydrate and then placing them in the anode compartment of the cell, containing a solution of sodium fluoride, 5 parts, and caustic soda, 15 parts, in water, 3,000 parts. Heats the electrolyte by the electrolyzing current.

651,849. June 19, 1900. Max Haas, Aue, Germany.

Cell for production of hypochlorites. Vertical, bipolar carbon electrodes, with direct or oblique perforations which are out of alignment.

655,239. August 7, 1900. T. Jespersen, Neenah, Wisconsin.

Electrolyzes dilute hydrochloric acid. Bleaches with the resulting solution and again electrolyzes. Electrodes may be placed in the beater-engine, the carbon anode lying flat in a recess in the bottom and covered by a screen of wood or brass cloth.

657,012. August 28, 1900. P. Schoop, Wildegg, Switzerland.

Parallel cells, each consisting of a narrow, shallow channel in a slab of glass, marble, porcelain, ebonite, paraffin, etc. A sheet of platinum-iridium foil is notched along one edge and bent into an S, the plain portion lining one cell and serving as cathode and the notched portion depending into an adjacent cell, as anode. Graphite electrodes may be employed. Electrolyte, a solution of sodium chloride, passes successively through different cells.

(*To be continued.*)

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## ELECTROLYTIC REFINING OF LEAD.

In this issue we print a paper by MR. ANSON G. BETTS, in which he gives full details concerning his lead refining process, which is one of the most interesting recent achievements in electrometallurgy. The problem is an old one. Twenty-five years ago, Dr. N. S. Keith devised an electrolytic process for refining lead. But the solution of the problem found by Mr. Betts is apparently the first one which enables the electrolytic process to enter into successful commercial competition with the older ordinary metallurgical methods. The drawback of the latter is that while all other impurities may be easily and cheaply removed, this is not the case with bismuth. Bismuth is a very obnoxious impurity in lead, especially if the lead is to be used for coloring matter. The fact that the electrolytic process furnishes lead completely free of bismuth appears to be the main argument in favor of the commercial success of the Betts process. Another advantage is the diminution of the danger of lead poisoning to which the workmen are exposed.

The novel feature of the process is the electrolyte, which is a solution of lead-fluosilicate, containing an excess of fluosilicic acid. It is easily prepared from inexpensive materials; it may be made to contain a considerable amount of dissolved lead; it conducts the current well, is easily handled and stored; it is non-volatile and stable under electrolysis. In his report on the electrochemical industries in this country, published in our last issue, Dr. F. Haber points out that the fact that other metals than lead are dissolved in very small quantities only in the electrolyte, should be of great importance, as the main danger to the successful operation of electrochemical processes lies in the solutions soon becoming foul.

As Mr. Betts states, the electrolyte takes up no impurities, except possibly a small part of iron and zinc. On the basis of a contents of 0.01 per cent. of zinc and soluble iron in the anodes, and on the basis of 150 cubic ft of solution required for every ton of lead turned out per day by the refinery, Mr. Betts estimates that in one year the 150 cubic ft. will have taken up 93 pounds of iron and zinc, or about 1 per cent. These impurities can accumulate to a much greater extent than this before they become objectionable. Mr. Betts also points out that the electrolyte may be easily purified in several ways. All these points are of great value, as they should assure continuity of operation.

An interesting detail of importance is the simple method by which a dense, coherent and solid cathodic deposit of lead is obtained. The lead "trees" produced under ordinary conditions are well known. When the Betts process was first operated with the pure fluosilicate solution containing an excess of fluosilicic acid, the lead grew from the cathode toward the anode, and in order to avoid short-circuits it became necessary

to periodically remove the cathode and roll down the lead. This difficulty was overcome by the addition of some gelatine or glue in small quantities to the electrolyte. With this addition to the solution a dense deposit of lead is obtained, its density being greater than can be produced by rolling the crystalline deposit, unless great pressure is used. We may hope, with Mr. Betts, that the success thus obtained in the electrolysis of lead, generally accepted as impracticable, may give some encouragement to the employment of similar methods in the treatment of some other metals; this hope appears justified, especially in view of the fact that in the Betts process it has been found to be possible to obviate the chief trouble—spongy deposits—by inexpensive means.

## THE FARADAY SOCIETY.

As was mentioned before in this journal, the (British) Society of Electrochemists adopted at its inaugural meeting, in the beginning of this year, the name Faraday Society. In this they followed the example of scientific imperialism set by the German Electrochemical Society, which changed its name last year into Bunsen Society. And in the same way as the Germans found it necessary to add the words "for applied physical chemistry," our British friends have adopted the explanatory sub-title "to promote the study of Electrochemistry, Electrometallurgy, Chemical Physics, Metallography, and kindred subjects." It is a long and well-sounding name, and any unimaginative person now knows exactly what the Faraday Society was founded for. But what is in a name? It is much more important to record deeds, and it is highly gratifying to state that the first real meeting of the Society, held on June 30th, a full report of which is given on another page of this issue, was an unqualified success, and shows that the members of the Faraday Society are earnestly striving to render the Society worthy of the glorious name it has adopted.

In his presidential introductory address, Dr. J. W. Swan pointed out that the new society is not in competition with any other society. A society that interferes detrimentally with, or uselessly overlaps the work of a kindred society, has no right to live. But where there is a section of the field of science or of industry lacking development, and that gives promise of reward for better cultivation, that has ample room for many more workers, without their inconveniently jostling one another, and that from the scientific point of view is attractive in many ways—in that case a new society may have the effect of inducing new workers or of stimulating the efforts of those already engaged in a too little cultivated field, and it seems in every way desirable. These are exactly the same conditions which led to the formation of the American Electrochemical Society, and nobody will deny that the latter has already done much good, and promises to do much more in the future. In the same way we trust that the work of the Faraday Society, by bringing together the British electrochemical scientists and engineers, will be fruitful for the development of the art and science of electrochemistry in general.

Four papers were presented at the meeting. Abstracts of the same will be found on another page of this issue. Dr. Lehfeldt summed up the extended theoretical researches, which, based on the principles of thermodynamics, have led in recent years to a thorough understanding of the chemistry and physics of the lead accumulator. Dr. Perkin described some simple and useful apparatus for electro-analytic purposes. Of the other two papers, that of Mr. Swinburne was thoroughly practical, and should be of great interest to every metallurgist; that of Mr. Whetham was a very careful and cautious plea for the dissociation theory. Mr. Swinburne's process of working complex sulphide ores should have a great commercial future, if the process should be found to work so well in industrial operation, as it has been found to work on a large experimental scale by Messrs. Swinburne and Ashcroft. If the essential steps of the process are expressed in simple formulas, as Mr. Swinburne does, or if they are reduced to a simple diagram, as is done on another page of this issue, the process indeed is simplicity itself—on paper. Viewed from the standpoint of the practical metallurgist with due consideration of the details, it may appear a rather wild scheme at first sight, but one has seen wilder schemes work.

The essential novel feature of the Swinburne process is the first step, *i. e.*, the complete change of the mixed sulphides into chlorides by means of hot chlorine. Mr. Swinburne is right in pointing out that it is the essential supposition of the success of his process that this change is complete. The formation of chloride of sulphur would be fatal to the process. The process, to be successful, must be cyclic with regard to the chlorine. Mr. Swinburne asks his critics, not to doubt that this can be accomplished; he and Mr. Ashcroft have succeeded in doing it on a large scale. On the other hand, Mr. Swinburne calls attention to the fact that in most text-books the action of chlorine on sulphides is stated to produce both chlorides of the metals and chloride of sulphur. One of the gentlemen who took part in the discussion of Mr. Swinburne's paper therefore suggested to scrap all text-books. We don't see any reason for such a radical course. We don't see any reason why the text-books should not be right as well as Mr. Swinburne. What is needed—in text-books, as well as in the minds of many chemists of to-day—is the recognition of the fundamental fact, well-known to everybody who has followed the development of modern physical chemistry, that the reaction which takes place between certain chemical substances depends upon the conditions under which it takes place: on the relative masses of the substances which participate in the reaction; on the temperature; on the pressure. By changing these conditions we can vary the results. Mr. Swinburne describes in general under which conditions the change of the sulphides into the chlorides is complete, and how the result changes when the supply of ore or chlorine changes, or the temperature varies. It would be interesting to study this problem more in detail and then express the results by a graphical method in the way as Roozeboom and Van't Hoff deal with such problems.

Mr. Whetham's paper is highly interesting, because it is probably the first time that a distinguished adherent of the dissociation theory sums up its case with due consideration of the numerous strong arguments which have been brought forward against the theory or certain parts of it in recent years. These arguments have been so strong, and are sup-

ported by experimental evidence of so much weight, that the adherents of the theory can no longer afford to remain silent. The question is at present, how much of the theory must be modified in order to obtain a satisfactory agreement with the facts, and what remains of the original theory? It is really this question which is answered in Mr. Whetham's paper; and in view of the importance which this question has at present, a rather full abstract of this paper is given on another page of this issue.

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Mr. Whetham starts with an outline of the work of Faraday, Hittorf and Kohlrausch, which led to the recognition of the important fact that every ion in an infinitely dilute solution has a definite specific ionic mobility, which is independent ot the nature of the other ions present. This is an experimental fact, and may be considered as strong evidence for mutual ionic independence. There is no doubt that we must attribute to the ions a certain freedom of migration. Mr. Whetham argues there are two alternatives: either the ions migrate independently of each other, in accordance with the dissociation theory, or they move through the solution by means of ionic interchange, in some such manner as is pictured in Grotthus' chain. To prove the latter assumption to be wrong, Mr. Whetham takes refuge to the kinetic of gases and applies it to solutions; this argument does not seem to be very strong; even for gases the kinetic theory has been used too often to prove by elaborate mathematics something that was known before, and the unqualified application of the kinetic theory of gases to the case of solutions is unwarranted, in spite of the analogy between gas pressure and osmotic pressure. Much stronger evidence in favor of ionic independence in very dilute solutions appear to be the relations which have been found to exist between the electric and osmotic properties of very dilute solutions; and Mr. Whetham is justified in stating that all the evidence is clearly in favor of the dissociation theory as long as we have to do with sufficiently great dilution.

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Mr. Whetham therefore sees no reason to change anything in the fundamental conceptions of the dissociation theory for very dilute solutions. He then turns to the other side of the picture, and discusses the applications to more concentrated dilutions. It is here where the difficulties arise, where discrepancies have been found between theory and practice. Mr. Whetham carefully analyzes them and shows the unwarranted assumptions which have been made in extending the theory from dilute to concentrated solutions. One of his chief points is that it is necessary to take account of the inter-ionic forces which seem to disturb the course of the phenomena, except at extreme dilution. In other words, the generalization by which we can go over from the special case of infinite dilution to higher concentrations, is not as simple as one has thought at first. This does not diminish the value of the theory for dilute solutions, but it should stimulate research in the direction of investigating the other limiting case, saturated solutions. It is interesting to note how cautious Mr. Whetham is in warning against extensions of the theory to cases for which experimental evidence has not been obtained, in order to avoid discrepancies between theory and practice. He carefully limits the realm in which the dissociation theory has been proven to be correct, to infinitely dilute solutions with water as solvent. In view of this extremely cautious statement of the present position of the theory of electrolysis, it is somewhat surprising that in the discussion of the paper one gentleman thought it necessary to break a lance for what he terms scientific liberalism. Perhaps he considered Mr. Whetham's paper to be too conservative.

## ELECTROLYSIS OF NON-AQUEOUS SOLUTIONS.

In this issue we publish abstracts of a series of papers presented by Dr. H. E. Patten and Mr. W. R. Mott at the Cleveland meeting of the American Chemical Society. The investigations recorded in these papers are separate parts of a systematic attack upon the problems of the course and mechanism of electrolysis in non-aqueous solutions. Dr. Kahlenberg and some of his co-workers have already done highly valuable pioneer work in the same direction. We may expect important theoretical results from this work. Aqueous solutions have been studied too exclusively in the past, and it appears that some results thus found have been assumed to apply to solutions in general without sufficient experimental proof. The study of non-aqueous solutions may reasonably be expected to shed new light on the theory of aqueous solutions, and to procure a more solid foundation for the general theory of solutions. Dr. Patten's experiments with zinc chloride dissolved in acetone show that even interesting practical results may be expected from these researches.

## ELECTROLYTIC PRODUCTION OF HYPOCHLORITES AND CHLORATES.

The Digest of United States Patents, prior to July 1, 1902, continues to deal with the electrolysis of the haloid salt solutions, and particularly of the chlorides. Those cell constructions whose primary object is the separation of the radicals for the production of caustic or carbonated alkali and chlorine have been considered, and the list of those whose purpose is to effect a combination of anode and cathode products to form bleaching or disinfecting agents (hypochlorites), is completed in the current issue. The Digest now turns to those cells which are designed to effect this combination under such oxidizing conditions as will yield chlorates.

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Chemically, a chlorate is a hypochlorite plus oxygen, just as a hypochlorite is a chloride plus oxygen; but from the standpoint of the electrolytic methods the hypochlorite does not necessarily appear as an intermediate product between the chloride and chlorate. The salient conditions which govern the formation of the latter are a moderately high temperature, above 40° C., and an absence of reducing conditions, this being secured by facilitating the escape of hydrogen from the bath and often by the addition to the solution of such highly oxidized compounds as the chromates. Some of the earlier commercial chlorate cells interposed a diaphragm between the electrodes and mixed the caustic and chlorine in a separate vessel, thus avoiding all tendency to reduction, but a fuller understanding of the conditions governing the reaction has led, here, as always, to a simplification of the devices, and these are now comparable in simplicity and efficiency to the hypochlorite cells.

## CONVENTION REPORTS.

In this issue we publish the reports of the first meeting of the Faraday Society, the Cleveland meeting of the American Chemical Society, and the Niagara meeting of the American Institute of Electrical Engineers, with abstracts of those papers which relate to electrochemistry or metallurgy.

Owing to limitations of space we must reserve for the next issue the full report of the International Congress for Applied Chemistry, specially written for Electrochemical Industry by Dr. H. Danneel and Mr. J. R. Clement. A brief outline of the proceedings of the congress was published on page 370 of our last issue.

## NOTES AND NEWS.

Ulke Copper-Nickel Process.—With reference to a statement in the review of Borchers' Elektrometallurgie des Nickels, in our July issue, page 398, on a proposed copper refinery of the Lake Superior Power Co., Mr. Titus Ulke writes to us as follows: "The Lake Superior Power Co., through its late manager, Mr. J. H. Clergue, some three years ago directed me to prepare plans for a large electrolytic refinery, which it was intended to install in the vicinity of Sault Ste. Marie or Sudbury."

Obituary.—We regret to report the death of Mr. Luther Stieringer, one of the foremost lighting engineers of the world, in his fifty-eighth year, on July 17, at Pasadena, Cal. In his young years he was highly successful in the field of gas lighting, but in the very beginning of electric lighting he recognized the importance of the new illuminant and joined Mr. Edison at a very early stage at Menlo Park. Among his many inventions are three systems of interior wiring now in universal use. Mr. Stieringer was probably best known to the general public as the ingenious pioneer in producing striking and beautiful effects in decorative lighting by means of incandescent lamps, especially in connection with large expositions.

Theoretical and Applied Electrochemistry.—Under this title Mr. Woolsey McA. Johnson has contributed an interesting article to the *Trinity Tablet,* issued by Trinity College, Hartford, Conn. "The field indicated in the title is too vast to treat in the limits of this short article. Even if the Olympian muses were entirely up-to-date, and one of them would consent to act as a stenographer, I could not hope to give more than an epitome of the subject. Not only is the field which it presents to the practical engineer the widest and most unexplored, but for pure research electrochemistry offers the student the best opportunity to extend the vast growing integral of human knowledge." The author gives a brief review of the development of theoretical electrochemistry from the work of Galvani and Volta, up to the electrolytic dissociation theory. Concerning the latter he says that it "has had strong support from the younger generation of scientists in Germany and in the rest of the world. It is, however, inadequate to explain all the facts, and it has been attacked more or less successfully by a number of men, chief of whom is Kahlenberg, of the University of Wisconsin. However, it is the only theory that can give a broad and general explanation of electrolytic facts—a faulty and imperfect explanation, it is true, but still the best one." Mr. Johnson briefly refers to the application of the electrolytic dissociation theory to biology and to the development, by J. J. Thomson, of the electron theory. He then turns to industrial electrochemistry. "Removed by long space, yet, after all, not so far distant from these theories which modify our thought and our philosophy, is the application of the experimental facts of electrochemistry into large scale industrial manufacturing, which industrial extension is slowly changing our social, moral, and political conditions. In reality these two forces, which at first glance might be considered to be diametrically opposite, are working along the same line and changing the old order of things giving place to the new." The author points out the wonderful chance which we have in America for the development of electrochemical industries. "No other country has such cheap power, cheap coal, cheap raw materials as the United States has. No other country has labor, capital, natural resources, engineering ability, and, most important of all, far-sighted, enterprising, optimistic business men in such abundance as the United States. This country, provided she tempers her enterprises with conservatism, and provided her captains of industry are able enough and broad enough and fair-minded enough to grapple the labor question, will have the supremacy of the world. Excessive speculation and its consequent extravagance and the labor question, which is engendered by these two, are the only clouds on the industrial horizon." The author refers to Niagara Falls, and then continues: "The future developments of the electrochemical industry will be amazing. We have a new cheap agent to apply, and naturally there are many places where its use must be profitable. Heretofore much was done by persistence in trying all possible experiments. Now scientific methods are applied to develop the process, and engineering principles to build the apparatus. Many institutions are offering courses to fit a student to become an electrochemist. We now have an able, well-edited paper, the Electrochemical Industry, and a society that has made a record for growth in a year." Mr. Johnson thinks that any man whose taste lies in engineering, or in applied science, would do well to take up either one of the two fields—electrical railroad engineering or applied electrochemistry. In his opinion, either of these two, a man of such tastes will have a good chance to live an active, happy life. "Incidentally he will be well reimbursed financially. This, however, should be a secondary consideration. Activity is the basis of true human happiness."

The Best Way of Rewarding Labor.—Mr. Andrew Carnegie has contributed to the July issue of *Cassier's Magazine* an address on "Capital and Labor Harmony, Partnership and Profit-Sharing Plans," from which we quote the following sentences:

"I never see a fishing fleet set sail without pleasure. Not a man in the boats is paid fixed wages. Each gets his share of the profits. That seems to me the ideal. It would be most interesting if we could compare the results of a fleet so manned and operated, with one in which men were paid fixed wages; but I question whether such a fleet as the latter exists. From my experience, I should say a crew of employees *versus* a crew of partners would not be in the race. The great secret of sucess in business of all kinds, and especially in manufacturing, where a small saving in each process means fortune, is a liberal division of profits among the men who help to make them, and the wider the distribution, the better. Unsuspected powers lie latent in willing men around us which need only appreciation and development to produce surprising results. Money rewards alone will not, however, insure these, for to the most sensitive and ambitious natures there must be the note of sympathy, appreciation, friendship. Genius is sensitive in all its forms, and it is unusual, not ordinary, ability that tells even in practical affairs. You must capture and keep the heart of the original and supremely able man before his brain can do its best. Indeed this law has no limits. Even the mere laborer becomes more efficient as regard for his employer grows. Hand service or head service, it is heart service that counts. One of the chief sources of whatever success may have attended the Carnegie Steel Company was undoubtedly its policy of making numerous partners from among the ablest of its men, and interesting so many others of ability in results. I strongly recommend this plan, believing that in these days of ever-increasing competition it will be the concerns which adopt this plan, other things being equal, which will survive and flourish." An excellent portrait of Mr. Carnegie is printed as frontispiece in the same issue.

## ELECTROLYTIC LEAD REFINING.*

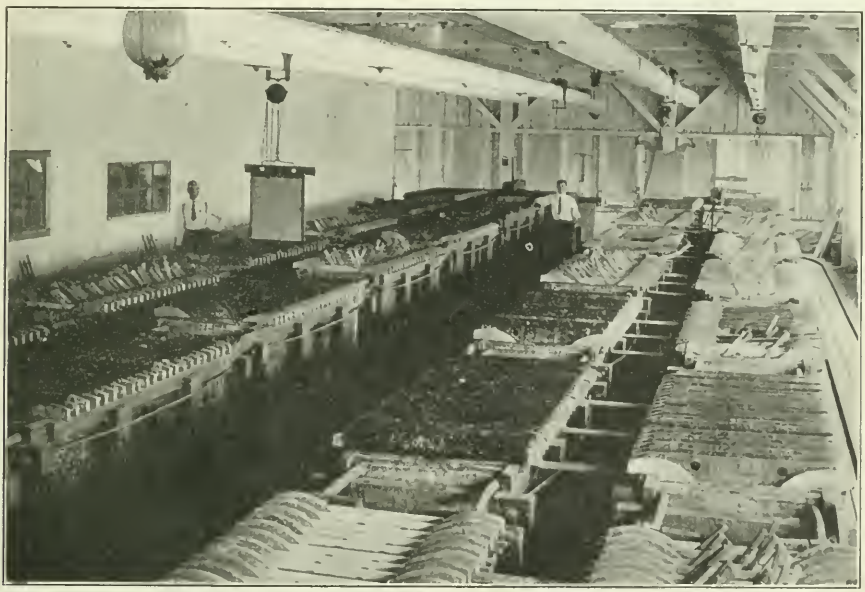
By Anson G. Betts.

A solution of lead-fluosilicate, containing an excess of fluosilicic acid, has been found to work very satisfactorily as an electrolyte for refining lead. It conducts the current well, is easily handled and stored, non-volatile and stable under electrolysis, may be made to contain a considerable amount of dissolved lead, and is easily prepared from inexpensive materials. It possesses, however, in common with other lead electrolytes, the defect of yielding a deposit of lead lacking in solidity, which grows in crystalline branches towards the anodes, causing short circuits. But if a reducing action (practically accomplished by the addition of gelatine or glue) be given to the solution, a perfectly solid and dense deposit is obtained, having very nearly the same structure as electrolytically-deposited copper, and a specific gravity of about 11.36—that of cast-lead.

Lead-fluosilicate may be crystallized in very soluble, brilliant crystals, resembling those of lead-nitrate and containing four molecules of water of crystallization, with the formula $PbSiF_6.4H_2$. This salt dissolves at 15° C. in 28 per cent. of its weight of water, making a syrupy solution of 2.38 sp. gr. Heated to 60° C., it melts in its water of crystallization. A neutral solution of lead-fluosilicate is partially decomposed on heating, with the formation of a basic insoluble salt and free fluosilicic acid, which keeps the rest of the salt in solution. This decomposition ends when the solution contains, perhaps 2 per cent. of free acid; and the solution may then be evaporated without further decomposition. The solutions desired for refining are not liable to this decomposition, since they contain much more than 2 per cent. of free acid. The electrical conductivity depends mainly on the acidity of the solution.

My first experiments were carried out without the addition of gelatine to the fluosilicate solution. The lead-deposit consisted of more or less separate crystals that grew toward the anode, and, finally, caused short-circuits. The cathodes, which were sheet-iron plates, lead-plated and paraffined, had to be removed periodically from the tanks and passed through rolls, to pack down the lead. When gelatine has been added in small quantities, the density of the lead is greater than can be produced by rolling the crystalline deposit, unless great pressure is used.

The Canadian Smelting Works, Trail, British Columbia, have installed a refinery, making use of this process. There are twenty-eight refining-tanks, each 86 inches long, 30 inches wide and 42 inches deep, and each receiving 22 anodes of lead-bullion with an area of 26 x 33 ins. exposed to the electrolyte on each side, and 23 cathodes of sheet-lead, about 1/16 in. thick, prepared by deposition on lead-plated and paraffined iron cathodes. The cathodes are suspended from 0.5 x 1-inch copper-bars, resting crosswise on the sides of the tanks. The experiment has been thoroughly tried of using iron-sheets to receive a deposit thicker than 1/16 inch; that is, suitable for direct melting without the necessity of increasing its weight by further deposition as an independent cathode; but the iron-sheets are expensive, and are slowly pitted by the action of the acid-solution; and the lead-deposits thus obtained are much less smooth and pure than those on lead-sheets.



ELECTROLYTIC LEAD REFINING ROOM OF THE CANADIAN SMELTING WORKS, TRAIL, B. C.

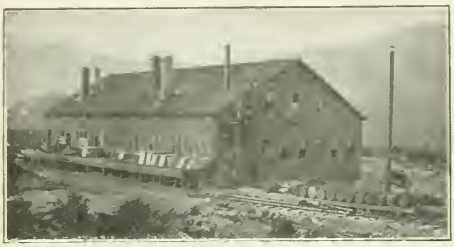
The smoothness and the purity of the deposited lead are proportional. Most of the impurity seems to be introduced mechanically through the attachment of floating particles of slime to irregularities on the cathodes. The effect of roughness is cumulative: it is often observed that particles of slime attract an undue amount of current, resulting in the lumps seen on the cathodes. Samples taken at the same time showed from 1 to 2.5 oz. silver per ton in rough pieces from the iron cathodes, 0.25 oz. as an average for the lead-sheet cathodes, and only 0.04 oz. in samples selected for their smoothness. The variation in the amount of silver (which is determined frequently) in the samples of refined-lead is attributed not to the greater or less turbidity of the electrolyte at different times, but to the employment of new men in the refinery, who

* A paper read before the American Institute of Mining Engineers. We are obliged to Mr. A. G. Betts for the photographs of his refining plant, from which the illustrations were reproduced.—Ed.

require some experience before they remove cathodes without detaching some slime from the neighboring anodes.

The shape of the electrodes, and the method of handling them to and from the tanks, are shown in the adjoining figure, representing the electrolytic lead refinery of the Canadian Smelting Works in Trail, B. C.

Each tank is capable of yielding, with a current of 4000 amperes, 750 pounds of refined lead per day. The voltage required to pass this current was higher than expected, as explained below; and for this reason and also because the losses of solution were very heavy until proper apparatus was put in to wash thoroughly the large volume of slime produced (resulting in a weakened electrolyte), the current used has



ELECTROLYTIC LEAD REFINERY, CANADIAN SMELTING WORKS, TRAIL, B. C.

probably averaged about 3000 amperes. The short-circuits were also troublesome, though this difficulty has been greatly reduced by frequent inspection and careful placing of the electrodes. At one time, the solution in use had the following composition in grammes per 100 cc.; Pb, 6.07; Sb, 0.0192; Fe, 0.249; $SiF_6$, 6.93, and As, a trace. The current passing was 2800 amperes, with an average of about 0.44 volt per tank including bus-bars and contacts. It is not known what was the loss of efficiency on that date, due to short-circuits; and it is, therefore, impossible to say what resistance this electrolyte constituted.

Hydrofluoric acid of 35 per cent., used as a starting-material for the preparation of the electrolyte, is run by gravity through a series of tanks for conversion into lead-fluosilicate. In the top tank is a layer of quartz 2 feet thick, in passing through which the hydrofluoric acid dissolves silica, forming fluosilicic acid. White-lead (lead-carbonate) in the required quantity is added in the next tank, where it dissolves readily and completely with effervescence. All sulphuric acid and any hydrofluoric acid that may not have reacted with silica settle out in combination with lead as lead-sulphate and lead-fluoride. Lead-fluosilicate is one of the most soluble of salts; so there is never any danger of its crystallizing out at any degree of concentration possible under this method. The lead-solution is then filtered and run by gravity into the refining-tanks.

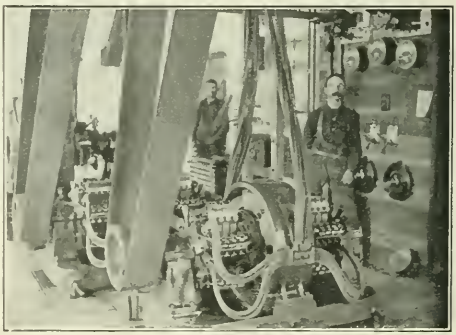
The solution originally used at Trail contained about 6 per cent. Pb and 15 per cent. $SiF_6$.

The electrical resistance in the tanks was found to be greater than had been calculated for the same solution, plus an allowance for loss of voltage in the contacts and conductors. This is partly, at least, due to the resistance to free motion of the electrolyte, in the neighborhood of the anode, offered by a layer of slime which may be anything up to ½ in. thick. During electrolysis, the $SiF_6$ ions travel toward the anodes, and there combine with lead. The lead and hydrogen travel in the opposite direction and out of the slime; but there are comparatively few lead ions present, so that the solution in the neighborhood of the anodes must increase in concentration and tend to become neutral. This greater concentration causes an e. m. f. of polarization to act against the e. m. f. of the dynamo. This amounted to about 0.02 volt for each tank. The greater effect comes from the greater resistance of the neutral solution with which the slime is saturated. There is, consequently, an advantage in working with rather thin anodes, when the bullion is impure enough to leave slime sticking to the plates. A compensating advantage is found in the increased ease of removing the slime with the anodes, and wiping it off the scrap in special tanks, instead of emptying the tanks and cleaning out, as is done in copper refineries.

It is very necessary to have adequate apparatus for washing solution out of the slime. The filter first used consisted of a supported filtering-cloth with suction underneath. It was difficult to get this to do satisfactory work by reason of the large amount of fluosilicate to be washed out with only a limited amount of water. At the present time the slime is first stirred up with the ordinary electrolyte several times, and allowed to settle, before starting to wash with water at all. The Trail plant produces daily 8 to 10 cu. ft. of anode residue, of which over 90 per cent. by volume is solution. The evaporation from the total tank-surface of something like 400 sq. ft. is only about 15 cu. ft. daily; so that only a limited amount of wash-water is to be used—namely, enough to replace the evaporated water, plus the volume of the slime taken out.

The tanks are made of 2-in. cedar, bolted together and thoroughly painted with rubber paint. Any leaks are caught underneath on sloping-boards. Solution is circulated from one tank to another by gravity, and is pumped from the lowest to the highest by means of a wooden pump. The 22 anodes in each tank together weigh about 3 tons, and dissolve in from 8 to 10 days, two sets of cathodes usually being used with each set of anodes. While 300-lb. cathodes can be made, the short-circuiting gets so troublesome with the spacing used that the loss of capacity is more disadvantageous than the extra work of putting in and taking out more plates. The lead-sheets used for cathodes are made by depositing about 1/16 in. metal on paraffined steel-sheets in four of the tanks, which are different from the others only in being a little deeper.

The anodes may contain any or all of the elements, gold, silver, copper, tin, antimony, arsenic, bismuth, cadmium, zinc, iron, nickel, cobalt and sulphur. It would be expected that



GENERATING PLANT, CANADIAN SMELTING WORKS

gold, silver, copper, antimony, arsenic and bismuth, being more electronegative than lead, would remain in the slime in the metallic state, with, perhaps, tin, while iron, zinc, nickel and cobalt would dissolve. It appears that tin stands in the same relation to lead that nickel does to iron, that is, they have about the same electromotive forces of solution, with the consequence that they can behave as one metal and dissolve and deposit together. Iron, contrary to expectation, dissolves only slightly, while the slime will carry about 1 per cent. of it. It appears from this that the iron exists in the lead in the form of matte. Arsenic, antimony, bismuth, and copper have electromotive forces of solution more than 0.3 volt below that of lead. As there is no chance that any particle of one

of these impurities will have an electric potential of 0.3 volt above that of the lead with which it is in metallic contact, there is no chance that they will be dissolved by the action of the current. The same is even more certainly true of silver and gold. The behavior of bismuth is interesting and satisfactory. It is as completely removed by this process of refining as antimony is. No other process of refining lead will remove this objectionable impurity so completely. Tin has been found in the refined-lead to the extent of 0.2 to 0.3 per cent. This we had no difficulty in removing from the lead by poling before casting. There is always a certain amount of dross formed in melting down the cathodes; and the lead-oxide of this reacts with the tin in the lead at a comparatively low temperature.

The extra amount of dross formed in poling is small, and amounts to less than 1 per cent. of the lead. The dross carries more antimony and arsenic than the lead, as well as all the tin. The total amount of dross formed is about 4 per cent. Table I. shows its composition.

TABLE I.—*Analyses of Dross.*

Analyses of the lead from which this dross was taken, see Table II.

| No. | No. in Table II. | Cu. Per Cent. | As. Per Cent. | Sb. Per Cent. | Fe. Per Cent. | Zn. |
|---|---|---|---|---|---|---|
| 1 | 2 | 0.0005 | 0.0003 | 0.0016 | 0.0016 | none. |
| 2 | 3 | 0.0010 | 0.0008 | 0.0107 | 0.0011 | " |

TABLE II.—*Analyses of Bullion.*

| No. | Fe. Per Cent. | Cu. Per Cent. | Sb. Per Cent. | Sn. Per Cent. | As. Per Cent. | Ag. Per Cent. | Au. Per Cent. | Pb. Per Cent. | Ag. Oz. p. T. | Au. Oz. p. T. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0075 | 0.1700 | 0.5400 | 0.0118 | 0.1460 | 1.0962 | 0.0085 | 98.0200 | 319.7 | 2.49 |
| 2 | 0.0115 | 0.1500 | 0.6100 | 0.0158 | 0.0960 | 1.2014 | 0.0086 | 97.9668 | 350.4 | 2.52 |
| 3 | 0.0070 | 0.1600 | 0.4000 | 0.0474 | 0.1330 | 1.0738 | 0.0123 | 98.1655 | 313.2 | 3.6 |
| 4 | 0.0165 | 0.1400 | 0.7000 | 0.0236 | 0.3120 | 0.8914 | 0.0151 | 97.9014 | 260.0 | 4.42 |
| 5 | 0.0120 | 0.1400 | 0.8700 | 0.0432 | 0.2460 | 0.6082 | 0.0124 | 98.0882 | 177.4 | 3.63 |
| 6 | 0.0055 | 0.1300 | 0.7300 | 0.0316 | 0.1030 | 0.6600 | 0.0106 | 98.2663 | 192.5 | 3.10 |
| 7 | 0.0380 | 0.3600 | 0.4030 | ..... | tr. | 0.7230 | 0.0180 | 98.4580 | 210.9 | 5.25 |

TABLE III.—*Analyses of Slimes.*

| Fe. Per Cent. | Cu. Per Cent. | Sb. Per Cent. | Sn. Per Cent. | As. Per Cent. | Pb. | Zn. | Bi. |
|---|---|---|---|---|---|---|---|
| 1.27 | 8.33 | 27.10 | 12.42 | 28.15 | 17.05 | none | none. |
| 1.12 | 22.36 | 21.16 | 5.40 | 23.05 | 10.62 | " | " |

TABLE IV.—*Analyses of Refined Lead.*

| No. | Cu. Per Cent. | As. Per Cent. | Sb. Per Cent. | Fe. Per Cent. | Zn. Per Cent. | Sn. Per Cent. | Ag Oz. p. T. | Ni,Co,Cd. Per Cent. | Bi. Per Cent. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0006 | 0.0008 | 0.0005 | ..... | ..... | ..... | .... | ..... | ..... |
| 2 | 0.0003 | 0.0002 | 0.0010 | 0.0010 | none | ..... | .... | ..... | ..... |
| 3 | 0.0009 | 0.0001 | 0.0009 | 0.0008 | " | ..... | 0.24 | ..... | ..... |
| 4 | 0.0016 | ..... | 0.0017 | 0.0014 | ..... | ..... | 0.47 | none | ..... |
| 5 | 0.0008 | ..... | 0.0060 | 0.0003 | ..... | ..... | 0.22 | ..... | ..... |
| 6 | 0.0020 | ..... | 0.0010 | 0.0046 | ..... | ..... | 0.22 | none | ..... |
| 7 | 0.0004 | none | 0.0026 | 0.0013 | none | 0.0035 | 0.14 | ..... | ..... |
| 8 | 0.0004 | ..... | 0.0038 | 0.0004 | " | 0.0 35 | 0.25 | ..... | ..... |
| 9 | 0.0005 | ..... | 0.0052 | 0.0004 | " | 0.0030 | 0.28 | ..... | ..... |
| 10 | 0.0003 | none | 0.0060 | 0.0003 | " | 0.0040 | 0.43 | ..... | ..... |
| 11 | 0.0003 | " | 0.0042 | 0.0013 | " | 0.0059 | 0.32 | ..... | ..... |
| 12 | 0.0005 | " | 0.0055 | 0.0009 | " | 0.0049 | 0.22 | ..... | ..... |
| 13 | 0.0005 | " | 0.0055 | 0.0007 | " | 0.0061 | 0.11 | ..... | ..... |
| 14 | 0.0004 | " | 0.0068 | 0.0005 | " | 0.0042 | 0.14 | ..... | ..... |
| 15 | 0.0003 | " | 0.0072 | 0.0003 | " | 0.0024 | 0.24 | ..... | ..... |
| 16 | 0.0006 | " | 0.0062 | 0.0012 | " | 0.0083 | 0.32 | ..... | ..... |
| 17 | 0.0006 | " | 0.0072 | 0.0011 | ..... | 0.0080 | 0.23 | ..... | ..... |
| 18 | 0.0006 | " | 0.0057 | 0.0010 | ..... | 0.0058 | 0.34 | ..... | ..... |
| 19 | 0.0005 | " | 0.0066 | 0.0016 | ..... | 0.0140 | 0.38 | ..... | ..... |
| " | 0.0005 | " | 0.0044 | 0.0011 | . | 0.0108 | 0.35 | ..... | ..... |
| 20 | 0.0004 | " | 0.0047 | 0.0015 | ..... | 0.0072 | 0.22 | ..... | ..... |
| " | 0.0004 | " | 0.0034 | 0.0016 | ..... | trace | 0.23 | ..... | ..... |
| 21 | 0.0022 | " | 0.0010 | 0.0046 | none | 0.0081 | 0.38 | none | none |

The electrolyte takes up no impurities, except, possibly, a small part of the iron and zinc. Estimating that the anodes contain 0.01 per cent. of zinc and soluble iron, and that there are 150 cu. ft. of the solution in the refinery for every ton of lead turned out daily, in one year the 150 cu. ft. will have taken up 93 lbs. of iron and zinc, or about 1 per cent. These impurities can accumulate to a much greater extent than this before their presence will become objectionable. It is possible to purify the electrolyte in several ways. For example, the lead can be removed by precipitation with sulphuric acid, and the fluosilicic acid precipitated with salt as sodium-fluosilicate. By distillation with sulphuric acid the fluosilicic acid could be recovered, this process, theoretically, requiring but one-third as much sulphuric acid as the decomposition of fluorspar, in which the fluorine was originally contained.

The only danger of lead-poisoning to which the workmen are exposed occurs in melting the lead and casting it. In this respect the electrolytic process presents a distinct sanitary advance.

TABLE V.—*Analyses of Bullion and Refined Lead.*

| | Ag. Per Cent. | Cu. Per Cent. | Sb. Per Cent. | Pb. Per Cent. |
|---|---|---|---|---|
| Bullion | 0.50 | 0.31 | 0.43 | 98.76 |
| Refined lead | 0.0003 | 0.0007 | 0.0019 | 99.9971 |

TABLE VI.—*Analyses of Bullion and Refined Lead.*

| | Cu. Per Cent. | Bi. Per Cent. | As. Per Cent. | Sb. Per Cent. | Ag. Oz. Per T. | Ag. Per Cent. | Au. Oz. Per T. | Fe. Per Cent. | Zn. Per Cent. |
|---|---|---|---|---|---|---|---|---|---|
| Bullion | 0.75 | 1.22 | 0.936 | 0.6832 | 358.89 | ..... | 1.71 | ..... | ..... |
| Refined lead | 0.0027 | 0.0037 | 0.0025 | 0.0000 | ..... | 0.0010 | none | 0.0022 | 0.0018 |

TABLE VII.—*Analyses of Bullion, Refined Lead and Slimes.*

| | Pb. Per Cent. | Cu. Per Cent. | As. Per Cent. | Sb. Per Cent. | Ag. Oz. Per T. | Ag. Per Cent. | Fe. Zn. Ni. Co. Per Cent. | Bi. |
|---|---|---|---|---|---|---|---|---|
| Bullion | 96.73 | 0.096 | 0.85 | 1.42 | about 275* | ..... | ..... | ..... |
| Refined lead | ..... | 0.0013 | 0.00506 | 0.0028 | ..... | 0.0008 | 0.0027 | trace |
| Slimes (dry sample) | 9.05 | 1.9 | 9.14 | 29.51 | 9 66.9 | ..... | 0.49 | trace |

TABLE VIII.—*Analyses of Bullion, Refined Lead and Slimes.*

| | Pb. Per Cent. | Cu Per Cent. | Bi. Per Cent. | Ag. Per Cent. | Sb. Per Cent. | As. Per Cent. |
|---|---|---|---|---|---|---|
| Bullion | 87.14 | 1.40 | 0.14 | 0.64 | 4.0 | 7.4 |
| Lead | ..... | 0.0010 | 0.0022 | ... | 0.0017 | trace. |
| Slimes | 10.3 | 9.3 | 0.52 | 4.7 | 25.32 | 44.58 |

*Silver not given. This was the case, also, with gold in the bullion. The slimes contained 0.131 per cent. of gold, or 39.1 oz per ton.

A plant for the operation of this process will consist of a power-plant, furnishing an electrolyzing-current of several thousand amperes, with a voltage depending on the number of tanks; a tank house, with electric cranes for handling a tank-load of anodes or cathodes at once; apparatus for making "starting" cathodes of sheet-lead; preferably of lead cut from sheets rolled at the refinery; pumps and storage-tanks for handling the electrolyte, and a cellar beneath the tanks for the passage of tank-cars removing that part of anode-slimes which falls from the plates. The finished cathodes, after rinsing, would be carried off to the lead-casting kettle. The casting-room would contain either a rotating or belt-conveyor, for passing the open anode-molds beneath the end of the siphon through which lead is flowing from the bullion-kettle. The bars of lead would be molded, as is usually done in refining works, by siphoning into a semi-circular row of molds. There would be either a washing, drying and sampling plant for the slime, in case it is sold, or a reduction-mill, if it is worked into bullion. The latter is much the best, if the location of the plant is not so remote that the express-charges on the bullion will balance the saving.

For the treatment of slime, the only method in general use consists in suspending the slime in a solution capable of dissolving the impurities and supplying, by a jet of steam and air forced into the solution, the air necessary for its reaction with, and solution of, such an inactive metal as copper. After the impurities have been mostly dissolved, the slime is filtered off, dried and melted, under such fluxes as soda, to a doré bullion.

The amount of power required is calculated thus: Five amperes in 24 hours make 1 lb. of lead per tank. One ton of lead equals 10,000 ampere-days, and at 0.35 volts per tank, 3500 watt-days, or 4.7 e. h. p.-days. Allowing 10 per cent. loss of efficiency in the tanks (we always get less lead than the current which is passing would indicate), and 8 per cent. loss in the generator increases this to about 5.6 hp-days, and a further allowance for the electric lights and other applications gives from 7 to 8 hp-days as about the amount per ton of lead. At $30 per year, this item of cost is something like 65 cents per ton of lead. So this is an electrochemical process not especially favored by water-power.

The cost of labor is not greater than in the zinc-desilverization process. A comparison between this process and the Parkes process, on the assumption that the costs for labor, interest and general expenses are about equal, shows that about $1 worth of zinc and a considerable amount of coal and coke have been done away with, at the expense of power, equal to about 175 hp-hours, of the average value of perhaps 65 cents, and a small amount of coal for melting the lead in the electrolytic method..

More important, however, is the greater saving of the metal-values by reason of increased yields of gold, silver, lead, antimony and bismuth, and the freedom of the refined lead from bismuth.

Tables II., III. and IV. show the composition of bullion, slimes and refined lead.

Tables V., VI., VII. and VIII. give the results obtained experimentally in the laboratory on lots of a few pounds up to a few hundred pounds. The results in Tables VI. and VII. were given me by the companies for which the experiments were made.

The success thus obtained in the electrolysis of lead, generally accepted as impracticable, may give some encouragement to the employment of similar methods in the treatment of some of the other metals, especially as it is shown to be possible to apply simple means to obviate the chief trouble, spongy deposits.

I wish to express my thanks to Mr. W. H. Aldridge, Dr. Edward F. Kern and Dr. William Valentine, of the Canadian Smelting Works, for their kindness in giving information and analyses.

## A METHOD FOR THE DETERMINATION OF CARBON IN CARBIDES.

By F. A. J. Fitzgerald and H. M. Loomis.

The description of Seward's apparatus and method for the determination of carbon in ferro-chrome, etc., in Electrochemical Industry, June, 1903, leads us to present a similar method devised to meet our requirements for the analysis of various electrometallurgical products, more particularly the carbides, such as those of silicon, titanium, etc. The use of sodium peroxide was first suggested to us by Mr. W. T. Gibbs of the Electric Reduction Company, Ltd., Buckingham, Quebec, Canada, and by the work of Mr. A. Edinger (Zeit. für Anal. Chemie, 1896). This method has been used by us for the past eight months in the analysis of silicon carbide, titanium carbide and similar compounds with satisfactory results.

The method used for the determination of carbon in silicon carbide by Moissan and Muhlhaeuser was heating the sample in a combustion tube with lead chromate, a very troublesome process. Speaking of silicon carbide, Moissan says:

"Le chromate de plomb attaque ce composé; mais pour le brûler complètement dans une tube de verre, il faut répéter l'operation plusieurs fois sur le même échantillon."*

Acheson, describing Muhlhaeuser's work on the analysis of carborundum, says:

"The great difficulty met with in obtaining a complete combustion of the carbon, necessitated the reduction of the sample to the finest powder: the samples used for the analysis being obtained by floating in water for some minutes, thus permitting the coarser particles to fall down and be separated from the finer."†

In carrying out our method 0.2 to 0.5 gram of finely powdered carbide is weighed into a nickel crucible of 30 cc capacity and mixed with about 1 gram of calcined magnesia, free from $CO_2$, and a quantity of fresh sodium peroxide, equal to 10 to 15 times the weight of carbon taken. The sodium peroxide must be weighed in order to make correction for the carbon dioxide usually present in this reagent. The magnesia keeps the molten caustic soda, formed by the subsequent reaction, in a porous and readily soluble state. The contents of the crucible are rapidly mixed with a platinum rod, and the crucible is then covered and placed on a triangle. A hydrogen generator, large enough to give a jet flame an inch or more in length, is started, the flame lighted and applied to the bottom and sides of the crucible. The reaction generally starts in 20 to 30 seconds, and is complete in 10 more. The contents of the crucible should now be quickly examined to see if the reaction is complete, as it should be if the mixture is thorough and in the proper proportions. The covered crucible is placed in a desiccator, charged with soda-lime, till quite cool, then transferred to a covered dish and the crucible contents extracted with tepid, recently boiled water. The solution, when all effervescence ceases, is transferred, and the crucible and cover rinsed into the flask of a Knorr's carbon dioxide apparatus, or the carbon dioxide may be determined by any suitable method. The carbon dioxide in the sodium peroxide is determined readily in Knorr's apparatus, and suitable correction made.

The question may be raised whether the method does not offer too much chance for the peroxide to absorb carbon dioxide from the air, thus introducing a variable error. In order to investigate this matter a careful determination of the $CO_2$ in a portion of a sample of sodium peroxide was made. Then another portion was taken for a blank analysis, where the whole procedure described above was carried out, except that there was no carbide present. The results obtained were as follows:

$CO_2$ found in sodium peroxide.....0.97 per cent.
$CO_2$ found in blank analysis.....1.00 per cent.

## FIRST MEETING OF THE FARADAY SOCIETY.

The first meeting of the (British) Faraday Society was held on the evening of June 30 at the rooms of the Chemical Society, Burlington House, London. The number of members is now nearly 250. The inaugural meeting was attended by fifty members. As the president, Dr. J. W. Swan, was unable to be present, Mr. James Swinburne took the chair and presented Dr. Swan's opening address, in which attention was called to the purpose and necessity of the society.

A paper by Dr. W. C. Dampier Whetham on the Present Position of the Theory of Electrolysis, and a paper by Mr. James Swinburne on Chlorine Smelting with Electrolysis, were read and discussed. The papers by Dr. R. A. Lehfeldt on the Total and Free Energy of the Lead Accumulator, and by Dr. F. M. Perkin on Electrolytic Apparatus were read in title and the discussion adjourned to the next meeting. In the fol-

* "Le Four Electrique," Paris, 1897, p. 353.

† "Carborundum: Its History, Manufacture and Uses."—Journal of the Franklin Institute, September, 1893.

lowing we give abstracts of the papers and a short account of the discussion which followed:

## THE PRESENT POSITION OF THE THEORY OF ELECTROLYSIS.

In the first part of his paper Dr. W. C. Dampier Whetham gave a short outline of our present knowledge of electrolytic conduction in aqueous solutions, the most important steps in the development being represented by the work of Faraday, Hittorf and Kohlrausch. The result of this work establishes the convective view of electrolysis; opposite streams of ions pass through the solutions with velocities indicated by Kohlrausch's theory and carrying their electric charges with them. To allow this migration, a certain amount of freedom is necessary; how this freedom is secured is another question.

Concerning this migration freedom, two alternatives seem to present themselves. Either the ions may migrate independently of each other, in accordance with the dissociation hypothesis, or else they may work their way through the solution by taking advantage of the successive formation and decomposition of molecular aggregates, or of collisions between the dissolved molecules, and the consequent possibility of ionic interchanges in some such manner as is pictured in Grotthus' chain.

"Let us assume for the moment the latter hypothesis, and trace the consequences. The solute molecules are scattered throughout a large volume of solvent, and, on this view, the ions work their way along from molecule to molecule of the solute, at the instants of collision between those molecules. Their velocities must, therefore, depend in some way on the frequency of collision, and this frequency, we learn from the kinetic theory, varies as the square of the concentration of the dissolved molecules. The ionic mobilities, then, will increase with the concentration probably approximately as its square, while the conductivity, which, on the convective idea, is proportional to the product of the mobility and the concentration, will vary more or less proportionately to the cube of the concentration. These consequences of the hypothesis are contrary to observation, which shows that in general the ionic mobilities only vary slowly with dilution, usually slightly falling as the concentration increases, while the conductivity of a dilute solution is directly proportional to the first power of the concentration instead of to its cube, and increases more slowly than the concentration as the solution becomes stronger. The view which refers the ionic mobilities to molecular interchanges is thus untenable, and we are driven to examine further the hypothesis of ionic dissociation."

The author emphasizes the point that "the dissociation indicated by the electrical properties of solutions is merely a dissociation of the ions from each other, and does not require the supposition that they are free from all chemical combinations; forces would certainly exist between the ions and the solvent, and there seems no reason to assume that chemical union between them cannot occur." Molecular complexes with an ion for a nucleus may exist, definite compounds may be formed, or some kind of double decomposition result in the production of new molecules in which an ion retains its electric charge. About these various possibilities the electrical evidence has nothing to say, an effective migratory independence from each other is all that the ions need to produce the observed phenomena.

The dissociation theory reached by the arguments outlined above, is supported, and was, indeed, originally suggested by other relations. The author gives a brief outline of the theory of the osmotic pressure in solutions. As is well known, direct osmotic determinations, as well as the results of experiments on the correlated properties, yield abnormally great values in the cases of aqueous solutions of electrolytes. It was van't Hoff's investigation of this phenomenon that originally suggested the idea of ionic dissociation to Planck and Arrhenius. "Since the thermodynamic theory shows that the osmotic pressure of dilute systems depends only on the number and not on the nature of the dissolved particles or on the nature of the solvent, when the osmotic properties have abnormally great values for dilute solutions, it must follow that the number of dissolved particles is greater than that calculated from the chemical formula weight; that is, dissociation must have occurred. It does not necessarily follow that the dissociation is that with which we have to deal when examining the electrical properties; whether it is or not, is a matter for further inquiry. Complicated molecules, dissolved in non-aqueous solvents, at any rate, seem sometimes to undergo dissociation into parts which are not electrical ions, for Kahlenberg has lately found that solutions of diphenylamine in methyl cyanide show abnormally low molecular weights and yet are non-conductors of electricity. On the other hand, it is difficult to see how more than one kind of dissociation is possible in such a molecule as potassium chloride, which we have already seen is dissociated into electric ions when dissolved in water."

According to the dissociation theory, there must be some relation between the equivalent conductivity and the osmotic phenomena. In infinitely dilute solutions the equivalent conductivity is constant (independent of the degree of dilution) and the dissociation into ions is assumed to be complete. We ought to find indications of this in the osmotic phenomena; if dissociation takes place into two ions (like in potassium chloride) the osmotic pressure and the freezing point depression should possess double their normal values. As far as we have experimental evidence on very dilute solutions, it is clearly in favor of the theory.

At higher concentrations, the equivalent conductivity diminishes, and this is held to denote incomplete ionization. The actual value of the equivalent conductivity, divided by its value at extreme dilution, is commonly taken as measuring the fractional coefficient of ionization, which can obviously be also calculated from osmotic data, on the assumption that each dissolved particle still causes the effect it would produce at infinite dilution. Many discrepancies between the values found by these two different ways have been discovered. But the author thinks that in this argument the assumption is made that there are no intermolecular effects; which is clearly wrong in all but extremely dilute solutions. "Experiments on the comparison of the electrical and the osmotic values of the coefficient of ionization are now seen to have little use from the point of view of the controversialist, seeking arguments for or against the ionic dissociation theory." But such comparisons furnish data which may enable a more complete theory than we yet possess to take account of the inter-ionic forces which seem to disturb the course of the phenomena, except at extreme dilution.

The modern theory of the galvanic cell involves both electric and thermodynamic considerations; it furnishes no evidence, one way or the other, about any definite electrolytic or ionic hypothesis. The phenomena of concentration cells may, however, be satisfactorily explained by the hypothesis of independent ionic diffusion, as has been shown by Nernst.

There is a close relation between the electrical ionization and the chemical activity of the dissolved substances in aqueous solutions, but there seems to be no valid theoretical reason which necessitates the extension of this relation to other than aqueous solutions, and it is possible that in other solvents, and for gaseous or fused systems, rapid chemical change may be brought about by non-electrical double decomposition. This conclusion is supported by an observation of Kahlenberg on the instantaneous production of a precipitate of copper chloride when hydrochloric acid is passed into a non-conducting solution of copper oleate in benzine. It is evident that such a result indicates that, in the particular solvent used, rapid chemical action may occur which is not correlated with appreciable electrolytic ionization, but it does not, in the least, affect the electrical and osmotic evidence in favor of the theory of the ionic dissociation of the aqueous solutions of electrolytes.

Nevertheless, it serves to caution us against extending the deductions of theory, which apply to simple aqueous solutions, to cases which have not been subjected to an adequate theoretical and experimental examination.

Ostwald's formula for the relation between electric conductivity and concentration—based upon the law of chemical mass action—has been shown to be valid for weak acids and other slightly conducting solutions, but has completely failed in the case of strong acids and other good conductors. The author points out that the deduction of this formula involves the assumption that there are no inter-molecular forces. We cannot expect, therefore, conformity with the dilution law in solutions where many dissociated ions are present.

In summing up, the author states that the phenomena of electrolysis and the osmotic properties of electrolytes clearly indicate that the conduction of a current through an aqueous solution consists in the convection of charged ions through the liquid, the ions being dissociated from each other while they are electrolytically active. But without definite experimental evidence, we cannot legitimately extend these conclusions, and when, as in fused salts, the conditions are entirely different, we have to recognize that an alternative explanation is possible. Conduction in a fused salt may be due to a mere possibility of interchange between the electrified parts of the molecules, without any permanent and definite dissociation. Some process in the nature of Grotthus' chain may, in this case, secure the migrating freedom necessary for electrolytic conduction. Whether this is so, or whether, as in solutions, the current is carried by ions dissociated from each other, their number being a function of the temperature, remains a question for future investigation.

In the discussion which followed, Dr. Lehfeldt called attention to the investigations of Jahn and Nernst on the dilution law for strong solutions. Dr. Lowry spoke on the filament of the Nernst lamp, which is to be considered as a mixture of solid electrolytes; from experiments which he has made, he concludes that for this case the same laws are valid concerning electric conductivity, as for other mixed solutions. Two written communications were read from Dr. Swan and Prof. Armstrong. The latter criticised the dissociation theory as involving unnecessary assumptions not in harmony with known facts and broke "a lance on behalf of the cause of scientific liberalism, now so unpopular and out of fashion amongst us." In his reply, Dr. Whetham said that although the early promoters of the electrolytic dissociation theory unduly neglected the action of the solvent, this is no longer the case now. He enlarged his remarks, given above, on the meaning of the term "free ions."

## CHLORINE SMELTING WITH ELECTROLYSIS.

In this paper Mr. James Swinburne described a new process covering an apparently wide domain in metallurgy. What is wanted to displace furnace reduction of oxides and sulphides is to convert the ores into salts of the metals, that can be easily and cheaply electrolyzed, and to do this simply, efficiently and economically.

His new process may be briefly summed up as follows: If there is a single sulphide, it is first treated with chlorine, so as to displace the sulphur and absorb all the chlorine; the chloride is then electrolyzed to get the metal and recover the chlorine. If there is a mixture of sulphides, say of zinc and of other metals, the process is in three stages: the first is the treatment with chlorine, in order to change all sulphides into chlorides; the second step is the chemical treatment of the mixed chlorides, by substitution, so that, finally, all the chlorine is combined with zinc; the third step is electrolysis of the zinc chloride to extract the zinc and recover the chlorine. This is the process in its naked simplicity.

If pure galena is to be smelted, it is treated with hot chlorine, so as to form lead chloride and sulphur. The sulphur is condensed as brimstone, and the lead chloride is electrolyzed in the fused state, producing lead and chlorine. If there is silver or gold present, the fused chloride of lead is treated with metallic lead. This replaces any gold or silver there may be, and the precious metals alloy with the remaining lead, so that, ultimately, a bullion is produced as rich as may be desired, the only limit being its melting point, which must not be too high.

The process is especially applicable to the treatment of slimes, such as Broken Hill slimes, "which are, at present, accumulating as a monumental memorial to the barbarity of present smelting processes." The slimes contain zinc, lead, iron, silver and gangue. Hot treatment with chlorine converts the whole of the metals into chlorides. The silver is extracted by substitution of lead, the lead is extracted by substitution of zinc, and the iron is thrown out as ferric oxide, not as metal, zinc oxide being used as substitute and the gangue is got out by filtration. Nothing is then left but zinc chloride, and this is electrolyzed to yield zinc and recover all the chlorine.

The process is perfectly cyclical concerning the chlorine. The chlorine merely goes round and round. The work takes in ore and electrical energy, and turns out metals, sulphur, and gangue. In treating sulphide ores with chlorine, as in analysis, or in the action of chlorine on sulphides generally, chlorides of the metals and chloride of sulphur are produced. This is the reaction described in most text books of chemistry. The formation of chloride of sulphur would, however, be fatal to the process, as both the chlorine and the sulphur would be lost, and there is no convenient way of getting rid of large quantities of this offensive compound

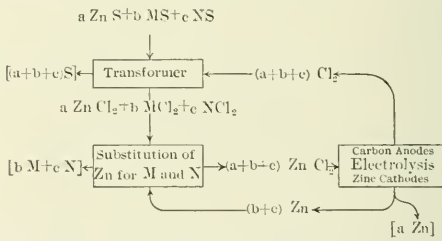



DIAGRAM OF THE GENERAL SCHEME OF THE SWINBURNE PROCESS FOR THE TREATMENT OF COMPLEX SULPHIDE ORES.

The ore is assumed to be a mixture of zinc sulphide and the sulphides of two other metals, which are designated by M, and N. The details of the second (chemical) step (substitution of Zn for M and N) are not given in the diagram, because they vary with the nature of M and N; for details, the reader is referred to the text. Final products are put in parentheses [ ]; a, b and c represent the numbers of grammolecules of the various materials.

far less of recovering the chlorine and sulphur. Decomposing with water is not a cyclic or a practical process.

The process is the joint invention of Mr. Swinburne and Mr. Ashcroft. Mr. Ashcroft came on the scene when the process was in the baby or test-tube and patent stage. They have worked the process on a large scale, and emphasize that this has been done with perfect success. "The discovery that sulphide ores can be decomposed on the large scale by chlorine, so as to give off sulphur and not its chloride, is, we may say it with modesty, a possible turning point affecting a vast realm of metallurgy."

Smelting Lead Zinc Bluestone.—As an example, the application of the process to the Broken Hill slimes is described in detail. The crushed ore is run into a transformer. This looks like a small blast furnace made of fire-clay with iron outside, or of lined iron. It runs continuously. When a tapping has just taken place, the transformer contains about a hundredweight of fused chlorides and gangue. The gangue almost floats in the chlorides. If much lead is present, much of the gangue floats, so there is no caking or silting up. The top of the transformer has a cone like a little blast furnace. Ore is poured into the fused chlorides, and at the same time chlorine

is blown in. The chlorine enters at the bottom by a sort of tuyere, which is a carbon tube. The cold part of this tube is connected to an iron pipe, which brings the chlorine. Dry, cold chlorine is easy to handle. It does not touch metals, and iron can be used freely. The chlorine bubbling through the fused bath displaces the sulphur, which comes off and is condensed. The action of chlorine on the sulphides in question evolves a great deal of heat, so that the transformer is self-heating and there is no coal or coke firing, or outside heating of any sort. The temperature is controlled by the rate of admission of chlorine and of ore. If the temperature is too low, chloride of sulphur may be formed. This may also be formed if there is a deficiency of ore supply. On the other hand, if the chlorine and ore are supplied too quickly, the transformer will get too hot, and some of the chlorides will distill over and be condensed with the sulphur. The temperature is the main consideration in determining the size of the transformer. It is best to have large transformers.

The pumping of the chlorine presents no difficulty, and a chlorine pump will run day and night continuously without trouble. The dryness of the chlorine is of vital importance here.

Now begins the second stage of the process. The fused mass from the transformer consists of chlorides of lead, zinc, iron, manganese, copper, silver, and gangue.* It is run into water and through a filter press when cool enough. This takes out the gangue and lead chloride, carrying most of the silver. The gangue is easily separated from the lead and silver chlorides, and these chlorides are then dried and fused in contact with lead, which extracts the silver and any gold; and then with zinc, which gives lead, practically pure, and anhydrous neutral zinc chloride, which is ready for the electrolysis vats.

The filtrate from the press contains** copper, iron, manganese and zinc. The copper is taken out as sponge or "cement" by zinc, and there are left iron, manganese and zinc chlorides. The iron is chlorinated up to the ferric state, and zinc oxide is added to cause precipitation. This throws down hydrated ferric oxide. This is the base of iron paint and is marketable, its value depending on the color obtained. The solution is further chlorinized in presence of more zinc oxide, and the manganese goes down as peroxide. Zinc has now been substituted for all the other metals in their chlorides, and nothing is left but zinc chloride.

This represents the second or intermediate or chemical step of the process. This step depends, of course, on the nature of the ore. If there is no copper, part is cut out altogether. If there is no iron, i. e., not even enough to hurt the zinc, the transformer product would not be dealt with in the wet way at all. The wet way is to get rid of iron and manganese, and to get out copper. Lead and silver can be got out by substitution in the fused state with great ease, but copper has too high a melting point, and is, therefore, taken out by the wet process.

The third step is the treatment of the zinc chloride. If it was obtained by the wet way, it is evaporated down carefully and fused. This decomposes some of the chloride and makes oxychloride. Steinhart evaporates in vacuo to produce neutral anhydrous zinc chloride. Swinburne and Ashcroft have not done this; they find that, with cautious boiling down, there is not much oxygen in the final result. This is got rid of in open preliminary vats, which use inexpensive anodes, which are gradually used up. The consumption is less than if all the oxygen went off as monoxide. The anhydrous neutral chloride from these vats is then added to that from the lead chloride substitution, and is taken to the final electrolysis vats.

The electrolysis vats are internally heated. The cathode is fused zinc and the anode is carbon. Some makes of carbon do not stand well, but suitable carbons serve to stand permanently. Of course, chlorine has no action on the carbons. The vats are kept under a very light suction, so that if there are any leaks air goes in instead of chlorine coming out. The carbons are not hot enough to be burnt by this small admission of air. As the vats are kept warm by the excess of the electrical power over the chemical, the larger the cell the lower the electromotive force. So far, 3,000 amperes has been the current used, but this means a very small vat. The output of fused salts is enormous in comparison with aqueous work. A 10,000-ampere vat is now being tried. Above that size the current will be inconvenient. With the small vats four volts per cell is needed; with 10,000 amperes three volts should do. It is best to count on four; this allowance ought to cover the power for the preliminary electrolysis, too. The current efficiency is practically 100 per cent. The vats are iron cases lined with fire-brick; the chloride soaks into the porous brick and solidifies somewhere, so it is really a vat with zinc chloride walls.

Cost of Process.—Any new process such as this, however satisfactory the results so far, involves risks of failure. "There are many chances of difficulties in working on a still larger scale, and chances of new and better processes coming out. The last chance is probably small, because the various problems of smelting copper, lead, zinc, antimony, tin, etc., have all been before the world for many years, and a new process that bids fair to solve all of them, in a new way, is not likely to be superseded, as regards many of them, by something else, though it might be as regards one of them. The only real risk is that of all new processes—unforeseen difficulties or expenses. The present process is too far advanced to leave many loopholes, but, even then, experience of other industries shows that it is not wise to embark in a new scheme, unless after the most searching criticism, the profits on paper are so large as to leave a very wide margin.

A considerable part of Mr. Swinburne's paper is devoted to the discussion of capital cost and working expenses. On account of limitations of space, we can only give here the results of three estimates made by him. The first refers to the treatment of bluestone ore in England with steam generating plant put up for the purpose. For a treatment of 100,000 tons of ore per year, a capital of $2,750,000 would be required; this allows nothing for payment of patent rights. The costs of working would be $2,626,000; the earnings, $4.332,000; hence, the profits, $1,706,000, or over 60 per cent of the capital invested.

If energy were bought at 0.8 cent per kw-hour, the costs would be increased by $279,000 per year, but the capital would be reduced to $1,375,000, making a profit of $1,427,000 on $1,375,000, or over 100 per cent.

The third estimate refers to a water-power plant on the waterway from the American lakes to the sea and to an ore containing 41 per cent of zinc, 15 per cent of lead and two ounces of silver per ton. For a works which smelts 100,000 tons a year, a capital of $2,500,000 would be required, of which half is process plant and half working capital. Electrical energy would be bought at, say, 0.2 cent per kw-hour. He estimates that the expenses would be $2,267,500; the earnings, $5,100,000; hence, the profits, $2,832,500, or over 100 per cent, before paying royalties.

From these estimates Mr. Swinburne concludes that the process is anything but expensive. In this process, a smelting works is independent of ore supply, in the sense that it can work any ores. If copper ores go up, it can devote its whole energy to zinc and lead, and so on, and the variety of ores is so great that the process cannot enhance the value of the ores to the miners. The supply of ores is thus practically unlimited.

## TOTAL AND FREE ENERGY OF THE LEAD ACCUMULATOR.

Dr. R. A. Lehfeldt presented an interesting theoretical paper, in which he summed up the various investigations on the total energy and the free energy of the lead accumulator, in

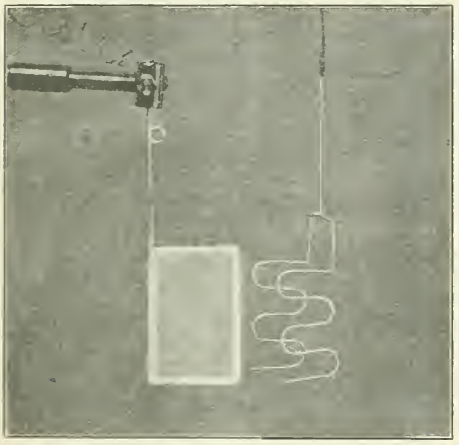
* The Broken Hill lines contain no copper. But the inventors have added purposely copper in some of their experiments, in order to study this more complicated case.

** It also contains a little lead and silver in solution, which are taken out with spongy copper.

order to show "how completely electrochemical theory has been found to harmonize with the experience of technicians, how satisfactorily it brings together many experimental facts and how suggestive it is." The double sulphate theory is assumed to be the correct one, and the thermodynamical argument is, in general, the same as that of Dolezalek, in his well-known book. The author has, however, collected and re-calculated the best data he could find for a comparison of theory and experiment, the results being given in tables and diagrams.

### ELECTROLYTIC APPARATUS.

Dr. F. Mollwo Perkin described a comparatively inexpensive form of platinum electrode for electro-analytic work. It is shown in the adjoining illustration. The cathode is in the form of a flag, and is made of platinum-gauze, which is held rigidly by means of a platino-iridium frame (10 per cent of iridium); the frame, which is roughened by means of the sand-blast, has a stout piece of iridio-platinum wire, welded on to it. The loop near the top of the wire is for hanging the electrode on the balance. The anode is made of iridio-platinum wire, and is bent upon itself in such a way that when it is placed into position for electrolysis (the cathode being placed midway between the two bent anode wires), an even current density is



PLATINUM ELECTRODES FOR ANALYTIC WORK.

obtained on all parts of the cathode. The distance between the two sides of the anode is 2.5 cm; therefore, when in position it is 1.25 cm distant from each side of the cathode.

The cathode is 6 cm high and 4.3 cm wide, and the length of the supporting wire is 7.5 cm, the loop being 2.5 cm from the end. The total surface is 50.4 sq. cm, that is, practically half a square decimeter, which, as the current density for analytical purposes is generally calculated per square decimeter of surface, is a very convenient size. It is not essential for the cathode to be made of gauze; in many cases, sheet platinum is quite as useful; but for metallic deposits which are inclined to exfoliate, such as bismuth and antimony, the gauze is more satisfactory; it is also very useful for mercury and for peroxide deposits. The gauze should not be too fine, as otherwise there is a tendency for hydrogen to collect upon the surface, and thus cause polarization. The finest gauze which he has found satisfactory is about 50 to 60 meshes per square centimeter.

For rotating electrodes, Dr. Perkin recommends the following arrangement: The end of a supporting arm of gun-metal is drilled to allow a spindle to pass. This spindle carries a small chuck (such as is used for fixing small drills on a lathe), which is used for fixing the rotator. The grooved pulley, which is fastened on to the upper end of the spindle, bears on the top of the arm which is ground smooth. The whole arrangement is driven by means of a belt from a water turbine or electric motor, and is found to give very perfect contact, and to work with very little friction. The parts should only be slightly lubricated, the best lubricant being a mixture of graphite and vaseline.

For making rotating lead electrodes, the author recommends the following method: Thin lead pipe, to which the vanes for mixing the liquid are burned, is drawn over a steel rod of the same diameter as the bore of the pipe. The steel rod protrudes about an inch above the top of the pipe, in order that it may be fastened in the chuck. The pipe is burned at the bottom and the top to prevent the solution from running in between it and the steel core. If a central core such as this is not used, lead electrodes are not sufficiently rigid to use for rotating purposes.

The author finally describes an arrangement in which the cathode is a rotating cylinder of platinum gauze, while the stationary anode is in the form of a double circle of stout platinum wire, and has four little baffles placed at intervals round it, to prevent the liquid from rotating with the cathode.

## NIAGARA MEETING OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

The annual convention of the American Institute of Electrical Engineers, held at Niagara Falls from July 1 to 4, was one of the most successful conventions ever held, the number of members and guests registered being nearly 500. About forty papers were presented, and their discussion was highly animated.

Besides a number of papers on miscellaneous subjects, most of the papers dealt with one of the following three general subjects which were under discussion at three different sessions: electric railroad engineering, electric high tension transmission, and the education of electrical engineers. The authors of the papers on engineering education were nearly all practical engineers, and it is interesting to note that all of them agreed that the college should teach principles, and nothing but principles; it should give a thorough general engineering education; specialization must come afterwards; they called for discipline, for mental training, to give students the ability to take up and handle new problems. In education it is quality that counts, not quantity.

In the following we give abstracts of those papers which are of special interest to electrochemists and metallurgists:

### THE LEGALIZED STANDARD OF E. M. F.

In his paper on this subject, Prof. Hy. S. Carhart, discussed the value of the e. m. f. of the Clark and Weston cells. While at the Chicago International Electrical Congress the value of the e. m. f. of the Clark cell at 15° C. was fixed at 1.434 volts, the German Reichsanstalt uses instead 1.4328 volts. Prof. Carhart endorses the Reichsanstalt in so far as he says that 1.433 is certainly nearer the truth than 1.434. Carhart and Guthe found it in 1899 to be 1.4333 (always at 15° C.). Barnes' recent determination of the mechanical equivalent of heat agrees with the previous measurements of Reynolds and Moorby, if the e. m. f. of the Clark cell is 1.43325 volts, and with Rowland's value, if it is 1.43355.

More recently Prof. Carhart has undertaken the measurement of the e. m. f. of the Weston cadmium cell, and the electrochemical equivalent of silver; this investigation is not yet completed. A number of cadmium cells have been prepared, and the several cells have been found to agree very well among themselves, the variations being smaller than is necessary to be within the limits of accuracy that have been set. The low temperature coefficient of the cadmium cell is an advantage of highest importance. The ratio of the e. m. f. of the Clark cell at 15° C. to that of the cadmium cell at 20° C. has been carefully determined in a series of experiments in the Reichsanstalt, in one of which Dr. Carhart participated, and found to be 1.40670. This ratio is known to a much greater degree of accuracy than the e. m. f. itself of either cell. An absolute

determination of the cadmium cell is, therefore, at the same time one of the Clark cell.

In order to work towards the proposed adoption of the Weston cadmium cell as standard of e. m. f., Prof. Carhart made the following recommendations: First, that the Institute appoint a committee to prepare a complete specification for the normal cadmium or Weston cell; second, that the cadmium cell, as thus specified, shall be adopted as the standard of the e. m. f. by the Institute, and that steps be taken to secure its legal adoption by Congress, provided it be dedicated to the public by the inventor, Mr. Edward Weston, one of the distinguished past presidents of the Institute.

These resolutions were seconded by Dr. Sharp, Mr. Hering and Prof. Goldsborough, and were carried. The committee to be appointed shall prepare its report at the earliest moment, so that it may be sent out for discussion previous to the meeting of the International Electrical Congress at St. Louis next year; at this congress, it is intended, final action shall be taken. Mr. Hering suggested that in order to avoid confusion, specific names should be given to the two types of cadmium cells in use: that with saturated solution and an excess of crystals as used by the Reichsanstalt, and that with unsaturated solution, as made by the Weston Company. The temperature coefficient of the latter is more nearly zero than that of the former; but the former is a well-defined electrochemical system while the latter is not. Mr. Hering suggests that the saturated one, being the real standard, should bear the name of Weston.

## THE ELECTRICAL EQUIPMENT OF A GOLD-DREDGE

Mr. Ralph L. Montague, in his paper on this subject, started with some general remarks on placer mining, *i. e.*, the process of extracting the gold from its surrounding gravel. It consists of feeding gravel and water into a rectangular trough (sluice box) set on a grade, on the bottom of which depressions or hollow spaces (riffles) are provided. The gold, owing to its high specific gravity, settles in these depressions, while the gravel is carried on down the sluice and dumped at the end. To accomplish this on a large scale, there must be sufficient grade to the deposit of gravel and its underlying bed rock to prevent the work-out gravel (tailings) from interfering with the excavating operations which are feeding the gravel into the sluice.

Where the natural grade is not sufficient for this purpose, a grade must be provided by artificial means. This is the purpose of the gold-dredge.* The excavating is done by an endless chain of buckets, which, revolving round the upper tumbler, dumps the gravel into a revolving screen (termed a grizzly). Jets of water play on the gravel and thoroughly wash it; the fine gravel and gold fall through the openings in the grizzly into a sump, from whence it is picked up together with sufficient water and elevated into the sluice box. The coarse gravel, large stones, etc., are allowed to fall overboard, being of no value. The gold, as already described, is recovered in the riffles forming the bottom of the sluice; the washed gravel carrying practically no values, falls over the lower end of the sluice and fills up the cut that was previously made by the dredge. The dredge is held in position by the anchor or spud at the stern, and side lines from the bow permit the buckets to be freed across the face of the cut. There are two spuds on a dredge; one is used for holding the dredge and the other is used when a cut is completed and it becomes necessary to step the dredge ahead. With this type of dredge it is possible to handle 0.85 cubic yard of gravel per hp-hour delivered on board.

The author described the first successful application of a gold-dredge in America, at Bannack, Mont., in 1895, and he discussed in detail the nature of the loads on the various motors, used in a gold-dredge. He remarks incidentally that at Oroville, Cal., where he is located, over 20 are in operation and building; each dredge has cost at least $50,000 and the ground to be mined previously worth from $2 to $10 per acre, sells now as high as $1,500 per acre. The author believes that not even 1 per cent. of the dredging ground in existence is at present being mined; the process is still in its experimental stage. Although good results have been obtained so far, there is no doubt but that more advanced methods, both mechanical and electrical, will be discovered in future to increase the efficiency of the process. He emphasizes that everything connected with the electrical part of the machinery on the dredge should be as nearly "fool-proof" as possible.

In the discussion which followed, Mr. Scott called attention to the flexibility of electric power in an industry of the kind, when power is wanted in fairly small units, and where it would be difficult to get it in other ways. He remarked that the application of electric power brings about great results in the mining industry. Mr. Skinner said it is interesting to see these dredges in actual operation; they go over ground that has been completely worked over by hand, and produce satisfactory financial returns; tremendously hard service is required of the motor which drives the buckets.

## CERTAIN UNDERGROUND HOISTING PROBLEMS ON THE WITWATERSRAND.

A paper on this subject was presented by Mr. A. W. K. Peirce. Gold mining on the Witwatersrand consists chiefly of the exploitation of the "Main Reef Series," a bed of gold-bearing conglomerate with an east and west strike, and dipping to the south at a fairly uniform angle in the neighborhood of 30°. For an extent along the strike of some 50 miles this reef series has been proved to be gold-bearing, and the continuity of the deposit has been proved by actual mining and by bore holes to such a depth on the dip that mining ground is held at a high valuation even where the ultimate mining depth cannot be less than 8,000 feet (vertical) or even more.

The permanence and the uniformity of average dimensions and values of their gold-bearing conglomerates make the mining in this area partake more of the nature of an industrial enterprise than is usually considered appropriate to mining ventures, which justifies the great attention that is paid to the engineering features of the work, and the large sums spent on the necessary mechanical equipment for the rapid and economical mining and reduction of the ore on a large scale.

The operation at the "Deep Levels" involve vertical shafts of 3500 to 5000 ft. to the intersection of the reef, with inclines from this point of 3000 to 6000 or more feet in length; in planning the development and equipment of these new properties, present hoisting methods must be considerably modified. The consensus of opinion among South African engineers seem to be that these "Deep Levels" will be operated on an even larger scale than has been obtained previously, the output planned for being 2000 to 3000 tons per mine per day; the greatest attention will be given to the economies that may be effected in working costs by the use of machinery, and in economic methods of operating the same.

The advantages of electric power distribution are well recognized, and it will be extensively adopted for what may be termed auxiliary power requirements. This is not an inconsiderable amount; it may be from 500 to 1500 kw per mine.

The principal power requirements of the mine equipment and the area over which the power is to be distributed (this being several square miles, with an added distance of in the neighborhood of a mile for each transmission to any underground installation) practically determine the use of a polyphase system at a moderately high voltage, especially as the ratio of the copper cost to power cost is about twice as great in the Transvaal as in most countries. However, for hoisting work on the scale indicated, direct-current motors are more suitable than alternating. After a detailed discussion of the whole problem the author concludes that the best method is the combination of polyphase transmission, conversion to direct currents separately for each hoist unit, and the utilization

* A view of an electrically operated gold-dredge was given in Electrochemical Industry, March, 1903, p. 263.

of the conversion machinery for obtaining suitable control of the hoisting operations by the "voltage control" or "Leonard" system.

## COPPER REFINING, GREAT FALLS AND ANACONDA.

In the concluding part of an elaborate paper, presented at the recent Albany meeting of the American Institute of Mining Engineers, Prof. H. O. Hofman, of the Institute of Technology of Boston, Mass., gave the following interesting comparison of the two electrolytic refining plants in the Butte district at Great Falls and Anaconda.

The work of these two refineries is of special interest as they work under different conditions of power, while they treat similar anode-copper by the multiple process. The works at Great Falls, driven by water-power, have 312 tanks, 9 ft. 9 ins. long by 2 ft. 4 ins. wide by 3 ft. 9 ins. deep, in three sets of 104 tanks, each set having a separate solution; a tank is charged with 20 anodes and 20 cathodes; the current is 40 amp. per sq. ft. of cathode area; two Westinghouse direct-current machines generate 9000 amp. at 200 volts. The works of Anaconda,* driven by steam power, have 1400 tanks, 8 ft. long, by 4 ft. wide, by 4 ft. deep, in sets of 200 each. A tank is charged with 76 anodes and 80 cathodes, the current is of 10 amp. per sq. ft. of cathode area. There are 7 dynamos, each generating 4000 amp. at 60 volts for 200 vats.

The anodes of the Butte district assay Cu. 98 to 99 per cent., Ag. 40 to 120 oz. per ton, Au. 0.1 to 1.5 oz. per ton. They are cast either direct from the converter or the converter-copper is first refined in a reverberatory furnace†

The converter-charge is blown to the point at which the copper still retains considerable sulphur dioxide in solution. In pouring anodes from the converter, the copper strikes a launder, swung in position, which delivers the copper into open flat moulds resting on a car moved slowly on rails laid between the posts of a stand. The strong evolution of sulphurous gas upon cooling makes the anodes very uneven. The moulds are of copper, but have cast-iron centers that take up the impinging force of the stream of metal. If the copper is first to be refined, the metal from several converters is emptied into ladles which discharge their contents into the stationary refining furnaces. Here the rabbling of the copper, in order to cause the oxidation necessary to produce set copper, has been replaced by forcing air into the copper by 1-in. wrought-iron pipes inserted through the side and end doors of the refining furnace. The two hours required for rabbling have been reduced to one and one-quarter hours by blowing; six feet of pipe are used up with a 40-ton charge. Oxidation is continued until a small ladle-sample, when broken, shows the characteristic single bubble in the depressed center. Care is taken to bring the copper only to this point, when the copper is saturated with cuprous oxide, as otherwise the surface will quickly become oxidized and covered with melted oxide. The set copper is then poled to tough-pitch copper, 15 poles (3 ins. at end, 7 ins. at butt and 15 to 18 ft. long) being required for 50 tons of copper. From the reverberatory furnace the anodes are cast by means of an improved form of Walker Casting Machine.‡

A tilting reverberatory furnace constructed along the general lines of the Brückner cylinder was used at the old Anaconda works, but given up after a short trial.

Converter-anodes are less evenly corroded, give more scrap and furnish a mud of lower-grade than do anodes from the refining furnace. Coarse copper, *e. g.*, with Cu., 99.27 per cent.; As. and Sb., 0.07 per cent.; Ag., 61.14 and Au., 0.22 oz. per ton, cast from the converters into anodes, gave 8 per cent. scrap, and the anode-mud, after having passed through a 40-mesh sieve, washed and dried, contained Cu., 41 per cent.; Ag., 7000, and Au. 18 oz. per ton. Similar copper, refined in the reverberatory furnace and then cast into anodes, gave in corroding only 5.5 per cent. scrap, while the 40-mesh anode-mud assay Cu., 18 per cent.; Ag., 15,000, and Au., 38 oz. per ton.

The Great Falls anodes are 24 ins. wide by 35 ins. long by 3 ins. thick at the top and 2½ ins. thick at the bottom; they are beveled at the bottom; the two lugs on top are 4½ ins. wide by 2½ ins. long by 2 ins. thick. The anodes are suspended from cast-copper cross-bars (1½ ins. by 1¼ ins.) by means of the Morrow clip,§ a loop of sheet copper, 2⅛ ins. wide (recently replaced by a rod ¼ in. in diameter) by 3½ ins. high, the ends of which are allowed to project into the anode moulds before they are filled with liquid-copper. A converter-anode weighs 500 lbs., and is sufficiently corroded in about 18 days to be withdrawn and regarded as scrap, a new anode being put in its place.

The Anaconda anodes are 24 to 24½ ins. wide, 32⅞ ins. long, and 1¼ ins. thick at the top, and 1 in. at the bottom. They have two top-lugs 6 ins. wide with holes, and are suspended in pairs from iron copper-covered cross-bars (½ by 1¾ ins.), 19 to a tank, by means of copper-hooks ⅜ in. thick. An anode weighs 230 lbs. and is corroded in 37 days.

The cathodes are made in the usual way, in tanks set apart for the purpose. They are slightly longer and wider than the anodes. At Great Falls they are 26 ins. wide by 36½ ins. long and weigh 2½ lbs.; at Anaconda they are 11 ins. wide by 33 ins. long and weigh ¾ to 1 lb. At Great Falls the cathodes are suspended by the Morrow clip, which is fastened to the starting-sheet by a machine,¶ which punches a hole through the loop and sheet, bends over the lugs and clamps them fast. At Anaconda the upper rim of the starting-sheet is bent and clamped over the ends of a piece of sheet-copper, 4½ ins. wide by 11 ins. long; 4 cathodes go to a cross-bar; the electrode-distance ranges from 1½ ins. to 2 ins.

The tanks are made of 3-in. plank and are lined with 8-lb. lead; the bottoms have a board-cover to protect the lead-lining from pieces of anode-copper that may become detached. At Great Falls, the vats are arranged in pairs with 3 conductor-bars, the central bar serving as cathode-bar for 1 tank, and as anode-bar for the other.†† At Anaconda, with the Thofern disposition, the tanks are arranged in single rows.‡‡

The electrolyte contains with the heavier current 170 gms. concentrated sulphuric acid and 42 gms. copper per liter; with the lighter current, 150 gms. acid and 40 gms. copper. The resistance appears to begin to increase when the copper rises above 42 gms. The temperature of the electrolyte at the head tank is 64° C. and 50° C., and the circulation, 6 and 3 gals. per minute. Solutions are admitted and drawn off, either at the ends or the sides, precautions being taken by means of perforated lead baffle-plates to have an even distribution, and thus avoid stirring-up any mud. The different forms of plunger-pumps, which were formerly used to raise the electrolyte, have given way to Pohle's air-lift pumps working under a pressure of 25 lbs. These have proved very satisfactory, especially since the delivery-pipe has been cut in two near the discharge and the ends joined by a rubber hose, thus breaking any electric connection. The electrolyte becomes enriched in copper and takes up iron, arsenic and antimony. A foul solution contained, e. g., per liter; Cu., 51.8 gms.; Fe., 13.2 gms.; As., 14.02 gms.; Sb., 0.62 gm; $H_2SO_4$, 48 gms.

The low percentage of antimony is due to the practice of adding daily enough concentrated crude hydrochloric acid to the head tank to maintain .04 gm. chlorine per liter in solution. This addition precipitates antimony, it is believed, as

* *Engineering and Mining Journal*, September 19, 1896.

† Refining converter-copper before casting into anodes was abandoned at Great Falls in spite of the advantages mentioned later on in the text as regards corroding, because the gain did not warrant the expense. At Anaconda, where power is generated by steam, it is of considerable advantage to have refined anodes.

‡ *Mineral Industry*, v. 7, p. 252.

§ *U. S. Patents*, No. 621,121, March 14, 1899; No. 631,471, August 22, 1899.

¶ *U. S. Patent*, No. 600,498, March 8, 1898.

†† Illustration in *The Mineral Industry*, vii., 186.

‡‡ *Berg-und Huttenmannische Zeitung*, 1893, p. 54.

oxychloride. When there is deficiency of hydrochloric acid, a sample-plate becomes streaked, tarnished, black, and, at the same time, brittle. The excess of copper over the normal is removed by shunting off part of the electrolyte and making it pass through tanks with lead anodes. By retarding the flow of this current through a second set of tanks, arsenic will be deposited with the rest of the copper. The slime deposited in such a purifying-vat showed Cu., 57.1 per cent.; $H_2SO_4$, 11.8 per cent.; Ag., 0. 3 per cent.; As., 7.2 per cent.; Sb., 1.8 per cent.; $H_2O$, 18.4 per cent.; difference: traces of $PbSO_4$ and traces of Fe.

*Comparison of the Great Falls and Anaconda Refineries.*

| | Great Falls. | Anaconda. |
|---|---|---|
| Number of tanks | 312 | 1,400 |
| Length " | 9 ft. 9 in. | 8 ft. 2 in. } inside meas. |
| Width " | 2 ft. 4 in. | 4 ft. 5 in. } |
| Depth " | 3 ft. 9 in. | 4 ft. 6 in. } |
| Number of tanks per set—*i. e.*, number of tanks using same solution | 204 | 200 |
| Number of anodes per tank | 20 | 38 |
| " cathodes per tank | 20 | 80 |
| " amperes per sq. ft. of cathode area | 40 | 10 |
| Power— | | |
| Number of generators | 2 | 7 |
| " circuit | 1 | 7 |
| Amperes generated per circuit | 9,000 | 4,000 |
| Volts per circuit | 200 | 60 |
| Character of material worked | Converter-anodes | Casting-furnace anodes |
| Kind of molds used | Copper | Iron |
| Casting-machines, pattern | Walker | Anaconda |
| Converter-anodes, per cent. Cu | 99.1 | |
| " " As. and Sb. | 0.07 | |
| " " oz. Ag. | 56.00 | |
| " " oz. Au. | 0.20 | |
| " " per cent. scrap | 8.00 | |
| " " mud, per cent. Cu | 41. | |
| " " " oz. Ag. | 7,000 | |
| " " " oz. Au. | 18 | |
| Refined-anodes, per cent. Cu | 99.27 | 99.25 |
| " " As. and Sb. | 0.07 | 0.10 |
| " " oz. Ag. | 61.14 | 90.00 |
| " " oz. Au. | 0.22 | 0.50 |
| " " per cent. scrap | 5.5 | 7.00 |
| " " mud, per cent. Cu | 18.00 | 10.00 |
| " " " oz. Ag. | 15,000 | 18,000 |
| " " " oz. Au. | 38.00 | 100.00 |
| Size of anodes— | | |
| Length | 35 in. | 32¾ in. |
| Width | 24 in. | 24½ in. |
| Thickness | 3 in., 2½ in. | 1¼ in., 1 in. |
| Weight in pounds, converter | 500 | |
| " " refined | 632 | 230 |
| Number of days corroding, refined-anode | | 37 |
| " " converter-anode | 18 | |
| Size of cathodes— | | |
| Length | 36½ in. | 33 in. |
| Width | 26 in. | 11 in. |
| Weight of starting-sheets, lbs. | 2½ | ¾, 1 |
| Weight of cathodes, lbs. | 55 | 100 |
| Number of cathodes on one bar | 1 | 4 |
| Electrolyte— | | |
| Sulphuric acid per liter, grams | 150 | 150 |
| Copper per liter, grams | 42 | 40 |
| Temperature at head tank, C° | 64 | 50 |
| Circulation per minute, gals. | 6 | 3 |
| Difference in potential— | | |
| Soluble anodes, per tank | .6 | .3 |
| Insoluble " | 2.5 | 2. |
| Composition of cathodes, per cent. Cu | 99.95 | 99.96 |
| " " " As. | .0012 | .0009 |
| " " " Sb. | .0033 | .0023 |
| " " oz. Ag. | 1.0 | 0.25 |

While the difference in potential between electrodes with soluble anodes is 0.6 (Great Falls) and 0.3 (Anaconda) volt, with insoluble anodes it rises to 2.5 and 2.0 volt. When iron is to be removed, the solution freed from copper and arsenic is concentrated by heating to one-third of its volume and then cooled, when most of the iron will crystallize out in the form of ferrous sulphate. At Great Falls the cathodes are renewed every second day. They weigh 55 lbs. and contain Cu., 99.95 per cent.; As., 0.0012 per cent.; Sb., 0.0033 per cent.; Ag., 1 oz. Although this method of working uses up a larger number of starting-sheets, it is found to be advantageous, as with the large current of 40 amp. there is a loss in efficiency on account of short-circuiting if the cathodes are allowed to grow heavier. Thus with 2-day cathodes there is an ampere efficiency of 91 per cent., while with 4-day cathodes this falls off to 85 per cent. The cathodes, taken out four at a time by means of an overhead traveling-pulley, are transferred to lead-lined cars and replaced by starting-sheets. The 20 cathodes in a car are then raised together by means of an electric crane, dipped into water, drained, dipped into milk of lime and allowed to dry. The coat of lime protects the plates in melting-down from the sulphurous gases in the products of combustion of the refining furnace.

At Anaconda, cathodes are removed only when the anodes are completely corroded. After two days depositing they are, however, taken out and straightened. A tank receives its anodes all at once; in the same way all the cathodes are taken out by one operation.

The anode-mud made at Great Falls is removed by a steam-injector pump and rubber-hose from the electrolyzing-vat into a settling-tank covered with a 40-mesh screen; it is then drawn off into an acid egg, forced through a filter-press, steam-dried (when it still retains 2 per cent. water), broken up, sampled, sacked and sold.

At Anaconda, the anode-mud is discharged through an opening in the bottom of the electrolyzing-vat, after the solution has been drawn off from the side, into a V-shaped trough leading into a tank; from this it is drawn into an acid-egg and forced into a tank in the refining-department, drawn onto filter-cloths, washed, dried, sampled, sacked and sold. Until recently the mud was treated at the works. It was melted down in a reverberatory furnace, refined by the addition of nitre, cast into small ingots and parted with sulphuric acid, the silver being precipitated by means of the copper.

The anode-scrap at Great Falls is remelted in the converter, while at Anaconda it goes back into the anode furnace.

The leading facts of the two refining-plants are brought together in the adjoining table.

## CLEVELAND MEETING OF THE AMERICAN CHEMICAL SOCIETY.

The twenty-eighth general meeting of the American Chemical Society was held in Cleveland on June 29 and 30. The following papers on electrochemical subjects were read by title: Dr. O. F. Tower, The Transport Number of Sulphuric Acid; Dr. Nevil Monroe Hopkins, Electrolytic Conduction With Reference to the Ion Theory; Dr. Arthur A. Blanchard, The Viscosity of Metallic Salts. A series of interesting papers on the electrolysis of non-aqueous solutions were presented by Dr. H. E. Patten and Mr. W. R. Mott, of the University of Wisconsin. Abstracts of these papers will be found below.

A trip which gave a view of one of the chief industrial centers of Cleveland, was made on a special chartered boat up the Cuyahoga River and out on the harbor lake; excursions were also made to the Newburgh Rolling Mills, the Lenox Chemical Company, the United Salt Company, and the new plant of the Cleveland Furnace Company.

## THE ROLE OF WATER IN THE ELECTRODEPOSITION OF LITHIUM FROM PYRIDINE AND FROM ACETONE.

Dr. H. E. Patten and Mr. W. R. Mott gave in a paper on this subject an account of an experimental investigation made in the University of Wisconsin. In determining the current-e. m. f. curve for lithium chloride dissolved in pyridine they found considerable variation in the decomposition point of the solution. With some solutions the correct decomposition point, 4.0 volts, was obtained. Other solutions showed upon electrolyzing for a time marked rise in resistance, so that a high voltage was required to pass a current. Addition of a little water caused immediate increase in the conductivity, but upon electrolyzing for a time the resistance again increased greatly. The first thought was, therefore, that exhaustion of the water caused the rise in resistance. But a number of independently prepared and thoroughly dehydrated solutions of lithium chloride in pyridine showed correct decomposition points, both across the total cell and at the anode and cathode

(by the normal electrode method). They could be electrolyzed continuously for hours, using a comparatively low voltage and low current density. Instead of an increase in resistance of the electrolyte, a slight decrease was observed (in spite of the stripping of the solution by the deposition of lithium) which was doubtless due to Joulean heat.

By adding a little water to one of these last anhydrous solutions during the process of electrolysis, a brownish film was seen to form on the cathode, over the lithium already plated out. Simultaneously the resistance rose. The solution had allowed 0.012 ampere to pass with 13.8 volts on the cell, a resistance therefore of 1150 ohms. On adding two drops of water (0.06 cc) to this solution, which was originally about 25 cc, and electrolyzing for about one hour, the current passed by 14.82 volts was only 0.0017 amp. The resistance was, therefore, 8710 ohms roughly. Interchanging the terminals of the cell, 10 volts passed 0.040 ampere through the solution alone, which is about the normal decrease in resistance upon adding 0.06 cc of water. The difference between 8710 and 250 ohms gives roughly the resistance of the film over 6 sq. cm, as 8460 ohms; or 1410 ohms per square centimeter. Upon electrolyzing for 5 minutes, the current had fallen to 0.006 amp. with 11 volts on the cell. The film could be seen on the cathode which had previously been used as anode. This observation was repeated many times and curves of the decrease of current with time at constant voltage determined and plotted. It is demonstrated, therefore, that the electrolysis of pyridine solutions proceeds regularly in the anhydrous condition, but is seriously interfered with by the presence of an undue amount of moisture, which causes the formation of a high resistance film upon the cathode.

The authors succeeded in depositing lithium from a solution of the chloride in acetone. It is not essential that the solution used should be highly anhydrous. Both carefully dehydrated solutions, and solutions made from Kahlbaum's chemically pure acetone with the commercial c. p. lithium chloride were electrolyzed and lithium deposited from them. As lithium reacts with water, the more anhydrous the solution the better. Lithium deposits equally well on platinum, iron, aluminium, and copper in an even coating which may be cut with a knife. Lithium can be deposited at a low current density from butyl alcohol.

## THE DEPOSITION OF METALLIC CALCIUM FROM ALCOHOLIC SOLUTIONS.

Dr. H. E. Patten, in a paper on this subject, describes experiments in which he electrolyzed a saturated solution of fused calcium chloride in etyhl alcohol, absolute from sodium, between platinum electrodes, 3 sq. cm in area, and approximately 0.7 cm apart, at 25° C. The current-e. m. f. curve shows a decomposition point at 1.7 volts. A large residual current was observed. Bubbles first came from the cathode at 2.1 volts, when 0.00186 ampere was passing. A white coating appeared on the cathode, and the resistance of the cell increased greatly. With 12 volts only 0.009 ampere passed. With 110 volts on the cell considerable current passed at first, but rapidly fell off owing to the thickening of this insulating film on the cathode. On interchanging the terminals, with 11.35 volts 0.01 ampere passed, which fell off in five minutes to a current smaller than could be read on the milliammeter. 0.5 cc of water was added to this solution, the original volume of which was 25 cc, and a second current-e. m. f. curve was determined. The decomposition point had now risen to 3 volts, and the conductivity was considerably increased. A second 0.5 cc. of water was added, and the solution subjected to a pressure of 110 volts, using a platinum wire of 0.16 sq. cm area as cathode. A current o 0.016 ampere passed, giving a current density of 0.10 ampere per square centimeter. Hydrogen was evolved in considerable quantity upon the cathode, and a metallic deposit, grayish white in color, was obtained. When the cathode is plunged into water, hydrogen is evolved. On allowing this metallic deposit to stand in the air, it changes with considerable speed, though by no means instantly, to a white coating, recognizable as a hydrated calcium oxide. Under a microscope of fairly high power this metallic deposit could be seen evolving a gas; evidently it was acting upon the moisture in the air. The formation of a hydride of calcium under these conditions is unlikely.

This effect of water in facilitating the deposition of calcium upon which metal it acts with such great vigor, is of special interest. It serves to emphasize the fact that the action of a solution upon a metal is not the prime factor in determining whether the metal can be deposited from the solution.

A saturated solution of fused calcium chloride in amyl alcohol was also electrolyzed. The same cell was used as for the ethyl alcohol solution. At 6.9 volts 0.00099 ampere passed and bubbles of gas could be detected rising from the cathode. An increase of resistance of the cell, similar to that noticed in the case of the ethyl alcohol solution, was observed in amyl alcohol. A white coating formed on the cathode. Using 110 volts, very little current flows, and after interrupting the current bubbles of gas do not continue to come from the cathode, so that the deposition of metallic calcium does not take place. Water was added to the amyl alcohol solution, but the conductivity was not sufficiently increased to raise the current density to the point where calcium is deposited. When this problem of the deposition of calcium had been suggested by Prof. Kahlenberg to him early last fall, the author electrolyzed solutions of calcium chloride in several solvents without success. After the solutions used in his present work stood more than eight months he succeeded in the electrodeposition, the failure of his first work being due to the use of too low a current density.

## THE DEPOSITION OF ZINC FROM ZINC CHLORIDE DISSOLVED IN ACETONE.

In a paper on this subject, Dr. E. H. Patten describes his experiments made in electrolyzing a saturated solution of zinc chloride in acetone between platinum electrodes 3 sq. cm in area, and approximately 0.7 cm apart, at 25° C. The current-e. m. f. curve shows a decomposition point at 2 volts. A large residual current was observed. At 0.9 volts 0.0014 ampere passed, remaining fairly steady. At 1.02 volts 0.0019 ampere steady current passed, no gas bubbles being visible on either electrode. A battery point was found at 1.27 volts during the first stage of electrolysis, but after electrolyzing perhaps one-half hour the battery point obtained was 1.32 volts. During the whole course of this electrolysis no gas bubbles appeared at either electrode. Chloroform, chlor-acetone, or other alkyl chlorides were formed at the anode, and a smooth, compact coating of zinc was deposited upon the cathode. The zinc may be deposited steadily with a current density of 2.25 amperes per square foot. He also used a current density as high as 40 amperes per square foot, but the zinc trees out from the edges of the cathode in long streamers; nevertheless, the zinc deposited upon the main portion of the cathode is smooth and dense. As one of the chief difficulties in the electrodeposition of zinc consists in avoiding the liberation of hydrogen upon the cathode and a consequent pitting of the coat, the availability of a solution such as this, where no hydrogen or other gas is liberated at a high current density, will readily be seen. The thickness to which zinc may be deposited from this solution has not, as yet, been determined. The author proposes to investigate this further, and also to make careful analysis of the zinc obtained from this solution. The difficulty of obtaining chemically pure zinc certainly warrants such an investigation. The apparent lack of carbonization of the salt, the lack of gas formation at the cathode, and the apparently complete fixation of the chlorine at the anode, taken together, look promising.

## THE DEPOSITION OF LITHIUM FROM VARIOUS ALCOHOLS.

In their paper on this subject, Messrs. H. E. Patten and W. R. Mott summarize the results of their work in depositing lithium from ethyl, propyl, butyl and amyl alcohols, lithium chloride being used in each case as solute. The solutions need not be highly anhydrous. For ethyl, propyl and amyl alcohols a high current density must be used, although the current-e. m. f. curves give a decomposition point at 4.0 volts even with a low current density. Butyl alcohol appears to be the best solvent from which to deposit lithium, although the solution has a low conductivity as compared with that of the ethyl and propyl alcohol solutions. Allyl alcohol and glycerine solutions were also tried, but gave no recognizable deposits of lithium even at a high current density.

## THE DEPOSITION OF SODIUM FROM A SOLUTION OF SODIUM IODIDE IN ACETONE.

Messrs. H. E. Patten and M. R. Mott, in their paper on this subject, describe experiments with the electrolysis of a saturated solution of fused sodium iodide in dry acetone; a deposit of metallic sodium was obtained on bright platinum. The specific conductivity of the solution used was found by the Kohlrausch method to be 0.231 at 25° C. The remarkable magnitude of this conductivity is seen by comparison with that of 0.02 normal potassium chloride in water, 0.00277. The current density used varied between 3.64 and 5.17 amp. per sq. cm. Hydrogen was copiously evolved upon the cathode; no diaphragm was used; the cathode was taken from the solution before the iodine could diffuse over from the anode. Plunged into water the sodium reacts vigorously, hydrogen being evolved. The metallic properties of the deposited sodium were otherwise clearly in evidence.

The conductivity of sodium iodide in acetone is so great that it can be used with a diaphragm very conveniently, though at the expense of considerable extra energy. Iodoform is formed at the anode, but not with sufficient speed to fix the iodine liberated.

A saturated solution of sodium iodide in pyridine was electrolyzed between platinum electrodes with a current density of 0.0666 amp. per sq. cm. The cell containing the solution was kept cool in a bath of ice water. A silvery white deposit at first appeared on the cathode, and after electrolyzing for 30 minutes a thick coating was formed which gradually separated from the cathode. The color of this coating is the same as that of the compound formed by the action of metallic sodium upon pyridine. Iodine is liberated at the anode faster than the pyridine can fix it, consequently the electrolysis of iodides dissolved in pyridine should be carried on with diaphragm.

A current e. m. f. curve for a saturated solution of sodium iodide in acetone with polished platinum electrodes was determined. The decomposition point obtained by extending the CR line back to the origin, is 1.4 volts. At 0.706 volt 0.000906 amp. passed through the cell and iodine separated at the anode; no gas bubbles were visible at the cathode to the naked eye, although, if calculated from Faraday's law, sufficient hydrogen would be generated by this current to be visible. The assumption that all the hydrogen, if liberated, is absorbed by the platinum appears hardly tenable, since with the same electrodes, using other solutions and a smaller number of coulombs, hydrogen appears very shortly—within 15 to 60 seconds—after the requisite voltage is applied.

In the case of a fresh solution of sodium iodide in acetone, as the pressure was gradually increased from 0.5 to 1.2 volts, only a residual current was observed, but at 1.2 volts a fairly steady current of 0.0016 amp. passed; and at 1.3 volts very minute bubbles of gas, hydrogen or some hydro-carbon came very slowly from the cathode, iodine being liberated at the anode.

After electrolyzing for two and one-half hours with an average current of 0.030 amp, and an average voltage of 1.7 (using platinum electrodes and a current density of 1.0 amp. per sq. decimeter) the resistance of the cell had increased from 32.79 to 53.7 ohms. The formation of a second phase was observed at the cathode clinging in drops. At the anode, iodine had crystallized out; this gives, with the vapor, at least four phases; the formation of a second phase by adding water to an acetone solution is well known.

Evidently water is a product of the decomposition of acetone. The solution of acetone reacts alkaline to litmus, after electrolysis. It appears, therefore, that sodium iodide is decomposed at a low voltage and low current density, but a high current density is required to deposit sodium from the solution. The evolution of hydrogen at the cathode is due to secondary reaction of the sodium deposited there upon the acetone. In general, the phenomena observed during the electrolysis in acetone solutions are analogous to those in aqueous solutions. Where the metal deposited does not react with acetone, hydrogen is not given off during the deposition of the metal at a low current density; as, for instance, in depositing zinc from zinc chloride dissolved in acetone.

## A DETERMINATION OF THE C R LINE FOR LITHIUM CHLORIDE IN TYPICAL SOLVENTS, ESPECIALLY SUCH AS YIELD POORLY CONDUCTING SOLUTIONS.

In a paper on this subject, Dr. H. E. Patten and Mr. W. R. Mott gave an account of a determination of current-e. m. f. curves for lithium chloride in a number of solvents. The results obtained in pyridine, acetone and various alcohols, and the analogous results obtained with other solutes, such as zinc chloride and calcium chloride, are given in the other papers, abstracted above. In this connection it is well to state that the series of papers presented by the authors at this meeting are separate parts of a systematic attack upon the problems of the course and mechanism of electrolysis in non-aqueous solutions. The solvents have been chosen as typical organic bodies, and electrolyzed using various typical solutes. The securing of suitable solutions for deposition of the metal has been the main object. Considerable data are already at hand and the work is still in progress.

The solvents used in this set of experiments were nitro benzene, aniline, dimethyl aniline, ortho toluidine, ethyl formate, ethyl acetate, diethyl oxalate, aceto-acetic ester, amyl butyrate, methyl cyanate, and ethyl benzoate. In general, it may be said that with high resistance and consequent low current density the CR line appears to start from zero. A number of instances of this occur in the energy diagrams for the above solvents, notably in the case of the nitro-benzene solutions, and in that of the ortho-toluidine solution. The currents measured were usually small. For instance, the resistance of nitro benzene solution in the cell used by the authors throughout the work, was 1,135,000 ohms; and for ortho toluidine 980,000 ohms. In the same cell lithium chloride in pyridine had a resistance of 24.9 ohms, while pyridine alone gave 312,000 ohms.

The solubility of lithium chloride in some of these solvents is, of course, slight, nevertheless the results obtained are of interest from their bearing upon the general problem of electrolysis. A detailed discussion of the various curves, found by the authors, will be given in their complete papers.

## COURSE OF STUDY IN ELECTRO-METALLURGY IN LEHIGH UNIVERSITY.

By Joseph W. Richards, Ph. D.

The course of four years study in this subject, offered at Lehigh University, was drawn up by the writer, and is intended to give to the student a thorough grounding in the elements of physics and chemistry, to build on this a compre-

hensive study of electricity and metallurgy, and so to fit the graduate to enter the fields of electro-chemistry or electro-metallurgy with a fair knowledge of the fundamentals of both electrical and chemical science.

A plan of the course is annexed, showing the studies taken up, arranged in four characteristic groups. In each group, most of the studies first taken are required as preliminaries to the succeeding studies, and even where this is not the case, the relation is more or less close. The figures annexed in parentheses show the number of exercises per week, an exercise representing one hour of lecture or recitation, or two hours of drawing or blowpipe work, or three hours of other laboratory work.

As thus constituted, the course comprises the following number of hours instruction in the four years:

*Culture Studies.*—English Language, English and American Literature, Rhetoric, Literary Criticism, Essays, Orations, Public Speaking—192 hours; German or French—96 hours; Hygiene—32 hours; Economics—32 hours; Philosophy of Religion—16 hours.—(Professors Thayer, Ringer, Stewart, Stewardson and Dr. Estes.)

*Mathematics.*—Elementary Mechanics—80 hours; Advanced Algebra—32 hours; Plane and Spherical Trigonometry—32 hours; Analytical Geometry—80 hours; Calculus—80 hours.—(Professors Thornburg, Meaker, Lambert.)

*Engineering Subjects.*—Physics and Physical Laboratory—272 hours; Electricity and Magnetism, and Electrical Laboratory—128 hours; Alternating Currents, Dynamos and Motors and Dynamo Laboratory—256 hours; Transformers, Transmission of Power, Electric Lighting and Heating—96 hours; Strength of Materials, Boilers, Steam Engine—128 hours; Machine Construction and Mechanical Technology—each, 120 hours in summer school.—(Professors Franklin, Esty, Merriman and Klein.)

*Mineralogy.*—Crystallography and Mineralogy—80 hours; Determinative Mineralogy with the Blowpipe—32 hours.—(Professors Frazier and Richards, and Mr. Landis.)

*Metallurgy.*—Metallurgical Drawing, Construction and Design—288 hours; General Metallurgy, Metallurgy of the Separate Metals, Problems, Metallurgical Laboratory—192 hours; Theory of Electrolysis, Electrometallurgy, Electrometallurgical Laboratory—128 hours; Blowpipe Assaying—32 hours; Ore Dressing—48 hours.—(Professors Frazier, Richards and Eckfeldt, Mr. Sullivan, Mr. Landis.)

*Chemistry.*—Lectures, Stoichiometry, Chemical Philosophy—112 hours; Qualitative Analysis—144 hours; Blowpipe Analysis—32 hours; Quantitative Analysis—480 hours.—(Professors Chandler, Shober and Ullman.)

*Thesis.*—Forty-eight hours work is assigned on the roster.

| | Culture Studies. | Mathematics and Engineering. | Metallurgy and Mineralogy. | Chemistry. |
|---|---|---|---|---|
| Entrance Requirements. | English, American History, German or French. | Algebra, Geometry, Plane Trigonometry, Elementary Physics. | | |
| First Year. | | | | |
| First Term. | English (3), Hygieoe (2), Germao or French (3). | Elementary Mechanics (5). | | Chemistry Lectures (2). Chemical Lab. (2). |
| Second Term. | English (2), Public Speaking (1), German or French (3). | Advanced Algebra (2), Trigonometry (2), Physical Lab. (1), Physics (2) | | Stoichiometry (2). Qualitative Analysis (3). |
| Summer Term. | | Constructive Elements of Machinery and of Electrical Apparatus (4 weeks). | | |
| Second Year. | | | | |
| First Term. | English (2), Public Speaking (1). | Analytical Geometry (5), Physical Lab. (1), Physics (3). | Crystallography (2), Drawing (3), Metallurgical Construction (1). | |
| Second Term. | English (2). | Calculus (5), Physical Lab. (1). Physics (3). | Mineralogy (3), Drawing (3), Metallurgical Construction (2). | Blowpipe Analysis (1). |
| Summer Term. | | Mechanical Technology (4 weeks). | | |
| Third Year. | | | | |
| First Term. | English (1). | Strength of Materials (4), Boilers (1), Electrical Lab. (1), Electricity and Magnetism (2), Dynamos and Motors (2). | Determinative Mineralogy with the Blowpipe (1). | Chemical Philosophy (3). Quantitative Analysis (3). |
| Second Term. | Technical Reading. German or French (1). | Steam Engine (3), Electrical Engineering (2), Electrical Lab. (1), Alternating Currents (2). | Metallurgy Lectures (4), Metallurgical Problems, (1). | Quantitative Analysis (4). |
| Fourth Year. | | | | |
| First Term. | Economics (1). | Engineering Lab. (1), Electric Lighting (2), Electrical Lab. (1), Dynamo Lab. (2), Theory of Electrolysis (1). | Blowpipe Assaying (1), Metallurgy Lectures (4), Electro-Metallurgy Lab. (1). | Quantitative Analysis (3). |
| Second Term. | Economics (2). | Engineering Lab. (1), Electric Power (2), Dynamo Lab. (2). | Metallurgical Lab. (1), Metallurgical Design (2), Electro-Metalurgy (1), Ore-Dressing (3). | |
| | Thesis (3), for Degree of "Electrometallurgist." | | | |

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

By Carl Hering.

## INDUSTRIAL ELECTROCHEMISTRY.

*The Application of the Electric Furnace in Metallurgy.*—A recent paper read before a meeting of the *English Iron and Steel Institute* by Albert Keller, the well-known French electrometallurgist, is interesting as coming from a man who has had extended practical experience in this particular line. The processes and apparatus of Keller are familiar to the readers of Electrochemical Industry from an illustrated description

which appeared in Vol. I, page 162. In the present paper he discusses the possibilities of establishing electric iron smelting furnaces. In his opinion the employment of electricity as a reducing agent is practicable from an economic point of view only when it is a question of manufacturing special qualities of iron from pure ore delivered at the works on favorable terms; or when it is desired to foster the iron and steel industry in a country hitherto undeveloped in this respect, into which all coal must be imported, where iron ore of good quality abounds, and where natural sources of power are available in the immediate neighborhood of the ore deposits. He states that he has determined experimentally that one kw year utilized in an electric refining furnace is capable of yielding about four tons of steel-making pig iron. In a general way, therefore, the reduction of iron ore by electricity, in a country possessing metallurgical works and equally good conditions of transportation throughout, is theoretically practicable only when the ore can be obtained at the same equal terms, and when the cost of the kw year does not exceed about $6.25. It must be borne in mind, however, that the scale of production of an electric furnace is less than that of blast furnaces, presumably meaning per dollar of first cost of complete installation, and that on this account establishments equipped for electric working would be of less capacity; the working expenses being also proportionately higher, it does not appear as if the reduction of iron ores, as far as the production of ordinary pig is concerned, will ever enter the sphere of practice in any European hydro-electric plant. A high degree of purity can be reached by the electric method of production, owing to the method of generating the heat which enables the action of the carbon to be limited strictly to that of a reducing agent. By this means the action of the sulphurous gases is, to a great extent, avoided; and since the quantity of coke required in the electric process per ton of iron, for reduction only, is so small, the very best qualities can be used for the purpose. It is, therefore, possible, with good ore, to obtain a pig iron which will compare in purity with the Swedish iron. A further advantage consists in the higher temperature of working which the use of electricity permits, without, however, causing an excess of carbon in the material. It is also possible, in consequence of the hot working, to form slags of ultra-basic character. There are still many countries in which the conditions would favor the adoption of an electro-metallurgical industry, where coal is scarce, but where, on the other hand, an abundance of good ore and water-power are available. Brazil, Chili, New Zealand and others come within this category. The author states that he is at present figuring upon a scheme for the installation of an important electro-metallurgical establishment intended for the production of iron and steel in Brazil. A concession has been granted to the syndicate of a waterfall capable, in the season of minimum flow, to supply a force of 25,000 hp. The work of confining the fall within channels has been contracted for under penalty for the sum of 2,500,000 francs. The cost of one hp-year is, therefore, 10 francs (about $2). Calculating that the amortization of the works, and also that of the hydraulic and electric plant, will be effected in ten years, the cost of one kw-year in such an installation will be less than 25 francs (about $5). The iron ore averages 65 per cent of metallic iron and is of remarkable purity, the cost, delivered at the furnace, being reckoned at 12.50 francs ($2.50) per ton; the conditions are, therefore, entirely favorable for such an enterprise. The above opinions of the author are given for the cases in which it is a question of the production of pig iron by the use of electricity. In regard to the production of steel directly from the ore, the author states that the cost of the electric energy no longer forms the principal factor in the cost of production. About 1.10 kw-years are necessary for the melting and refining of one ton of steel produced by the fusion of scrap iron and steel; and even if the motive power is produced by a steam engine, the expenditure of electric energy will approximately amount to only 40 francs per ton of steel. This outlay, says the author, resulting under the least favorable conditions of generating power, can scarcely form an obstacle to the refining of steel of superior quality by the electric method. The author gives an outline of a steel plant, for an application of his process. The furnaces should be placed in line, abreast of each other. Two refining furnaces are preferably arranged in front of each smelting furnace, each of which will receive the metal alternately, while refining is being completed in the other. A more practical arrangement suggests itself where a large amount of power is available. The charges of all the reducing furnaces could be run off into a single ladle on a bogie traveling along the front of the battery of furnaces. The metal thus collected could be refined directly by bringing the ladle beneath an arrangement of electrodes, or it might be tapped into a refining furnace of a capacity sufficient to receive the whole. Two such furnaces would then serve the whole battery of smelting furnaces, for if the latter were tapped every three hours, there would be six

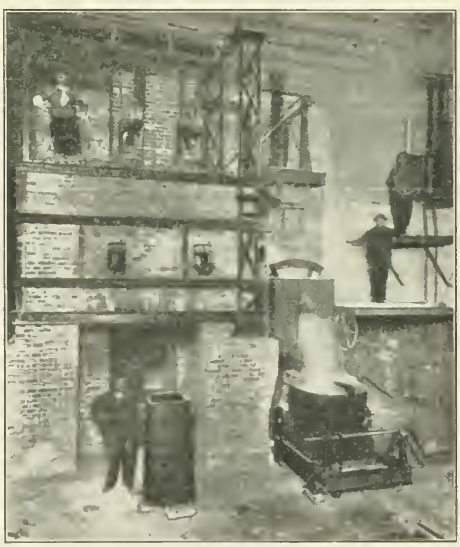


FIG. 1. KELLER ELECTRIC FURNACE.

hours available for refining, tapping and repairing the hearth and walls. An electric metallurgical works laid out on this plan, having available a force of 10,000 hp on the shaft of the turbines, could produce 60 tons of steel per day, of which 50 tons would be yielded by the smelting furnaces working on 55 per cent ore and 10 tons by the smelting of scrap. As far as possible, the power should be generated by single-phase, alternating-current dynamos subdivided into groups of 1000 hp each. Of these, eight would supply current to the smelting furnaces, and the other two would be devoted solely to the operation of refining. At Livet, where the Thermo-Electric Company, of Paris, had installed appliances for the production of steel by electricity, the electric generators develop 1200 hp each, by means of single-phase alternators of the Thury system, delivering a current of 30,000 amperes each. The adjoining illustration shows one of the electric-blast furnaces, which is capable of producing 12 tons of steel from the ore in 24 hours, with the refining hearth placed at its base. If, instead of smelting ores, scrap iron or steel is melted, the capacity of the furnace would be 25 tons of steel per day. As regards the cost of production, it was stated before that 2800 kw-hours (about 0.3 kw per year) were absorbed in producing one ton of steel, and assuming the cost of a kw-year of 8400 hours to be

about $10, including cost of amortization, the cost of energy for one ton of steel will be about $3.50. To this must be added the cost of ore, flux, electrodes, labor and maintenance, which together bring the total cost of production for one ton of ingot steel up to from $18 to $20, not including royalties paid for the exclusive right of working the process. An abstract of the paper of Keller is published in London *Electrician*, June 5.

*Harmet's Electric Iron Smelting Furnace.*—The latest furnace construction of Harmet for the smelting of iron by electricity is described and illustrated in an article in *L'Industrie Electrochimique*, for June. It consists of three parts, respectively called calcinator, reductor and regulator. In the first part the drying, roasting and calcination of the ore takes place. In the reductor the ore is mixed with carbon and subjected to the action of carbon monoxide, and arriving at the lower part of the reductor the material is fused by the help of an electric current, passed in through carbon electrodes. The apparatus is illustrated in the accompanying diagram. The

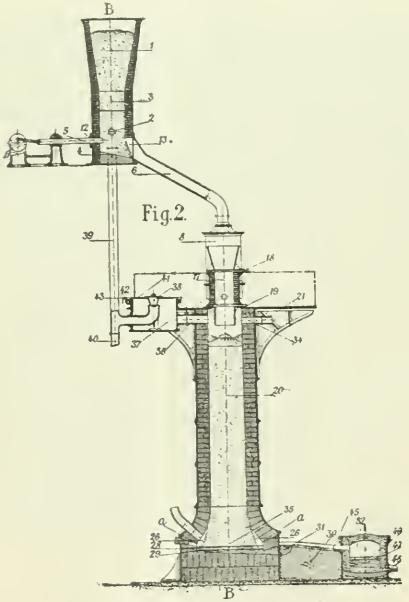



FIG. 2.—HARMET ELECTRIC FURNACE.

raw materials are charged into the calcinator, and heat for their drying and calcination is furnished by tuyeres 2, to which the combustible gases given off in the second part of the apparatus are conducted through pipe 39, and are burned. The charge arrives red hot on the bottom 4 of the calcinator, and is pushed down in that condition into the reductor by means of a reciprocating piston 5. Two tubes 6 are provided, one at each side of the furnace, which are alternately opened and closed by a mechanism arranged for that purpose, and alternately deliver a quantity of material into the reductor. On entering into the upper part of the reductor, the materials are mixed with carbon, which is introduced through the central charging apparatus 17. During descent the oxides are reduced, and, arriving in the crucible, the whole is fused by carbon electrodes 27. In order to assist the electric current in furnishing heat for the reduction, a part of the gases, arriving at the top, is also drawn off and conducted into the crucible by means of pipe 21 and blower 22, through pipe 23 and 26. The carbon electrodes extend far enough to be in contact with the slag, and have, therefore, to be maintained constantly in contact with the latter, even when the slag is drawn off. The slag forms the heating resistance. From the reductor the pig metal runs into the regulator, which consists of a circular chamber, provided with the necessary charging and tapping holes for metal and slag. It is heated by two electrodes, which enter through the roof or the sides, and can be either vertically arranged or inclined. The refining of the metal takes place in this furnace.

*Stassano Process of Electric Smelting.* The French patent specification of the latest construction of the Stassano furnace for the smelting of iron ores and the production of steel directly from the ores by electricity is reprinted entirely in *L'Industrie Electrochimique*, May, with the illustrations taken from the patent specification. The outlines of this furnace are familiar to the readers of Electrochemical Industry, the process having been illustrated in Vol. I, page 247.

*Manufacture of Sodium.*—The electrothermic process for the manufacture of sodium, invented by H. Becker, is shortly described in an article by the latter in *L'Industrie Electrochimique*, June. By heating, in an electric distillation furnace, chromate of sodium and carbon, there is produced, on the one hand, sodium, which distills off and can be collected in a condenser, and, on the other hand, metallic chromium, which can either be run out of the furnace in a molten condition, or can be taken out after the furnace cools off. By treating mixtures of salts of other metals, or mixtures of such salts and oxides, it is possible to produce alloys. For instance, by heating sodium chromate and sodium aluminate with a sufficient quantity of reducing agent, there is obtained a chromium-aluminium alloy and sodium, which latter distills off. Becker broadly proposes to reduce, in an electric arc or resistance distillation furnace, chromates, manganates, tungstates, ferrates or other salts, of which the acid radical is metallic and one of the metals of which is more volatile than the other, by carbon or metallic carbides, with the object to produce simultaneously the metals of the salts, the separation being effected by the sublimation of one of them. This reduction can be performed with or without addition of materials, which do not play any role in the chemical process, but are added in order to render the mixture more or less fusible, as the case may be. The author also describes the Cowles process for the reduction of sodium aluminate for the production of aluminum carbide and metallic sodium, which latter distills off. If iron or copper is added to the sodium aluminate, ferro-aluminium or cupro-aluminium is obtained instead of the carbide of aluminium.

*Process of Extraction of Metallic Calcium.*—Efforts to produce metallic calcium on a large scale, by the electrolytic method, continue to be made, in spite of its being a matter of considerable practical difficulty. The *Electrochemische Werke* have obtained a patent for a process in France, which is reprinted in full in *L'Industrie Electrochimique*, May. The apparatus in which the electrolysis is conducted is described as a simple furnace, the walls of which are constituted of a carbon cylinder, which is in electrical connection with the positive pole of a source of current. The cylinder is closed at the bottom by a cooling body, and isolated from the latter by a clay cylinder. The cathode is formed of a rod of iron, which is fixed to the cooling body. To assure tightness, the bottom of the furnace is provided with a thin layer of fluorspar. The main point, in which the process differs from others, is that the electrolysis is conducted at such a temperature that it does not reach above the melting point of metallic calcium. Fused calcium chloride is, by preference, used as electrolyte, and by using a very small cathode the metallic calcium separates on the latter, in a spongy state, sufficiently coherent, so that it can be taken off. This mass, as such, contains 50 per cent to 60 per cent of metallic calcium. It is, however, possible to compress the mass in a suitable way; as, for instance, with a pair of large tongs, and to squeeze it into a compact mass, which, after cooling, presents a metallic fracture, and contains nearly 90 per cent of calcium as metal.

*Carbide as Raw Material for Lamp Black.*—In the *Zeit-*

*schrift fr. Carbidfabrikation,* May 22. Dr. F. Goldschmidt mentions several processes for the manufacture of acetylene black. The process of Hubon consists in exploding acetylene by electricity under a strong pressure, not less than three atmospheres. Under these conditions acetylene decomposes, according to the equation $C_2H_2 = C_2 + H_2$, with separation of carbon in the form of a very fine, deep-black product. An establishment in Switzerland (Lonsa) is stated to use this process. Practical results obtained with the process have not been available; the author thinks that the decomposition of acetylene in larger quantities in this manner is accompanied by a tarry decomposition, which deteriorates the value of the product. It is, therefore, possible to work only smaller quantities at one time. Another process, which is said to be about to be applied for manufacturing on a practical scale, is the one of Ad. Frank and N. Caro. It consists in the action of carbon monoxide, or carbon dioxide on carbides, or acetylene. The two investigators have found that carbides burn in carbon monoxide, or carbon dioxide, and in such a manner that the calcium of the carbide combines with the oxygen of these oxides, while carbon is liberated, according to the equation $CaC_2 + CO = CaO + 3C$; $2CaC_2 + CO_2 = 2CaO + 5C$. The reaction takes place quantitatively, partly with the evolution of large amounts of heat. If, for instance, carbon monoxide or carbonic acid is conducted over barium carbide heated to 250° to 300°, incandescence appears at the place where the gas comes into contact with the carbide, until the whole of the carbide has been decomposed. For many brands of carbon it is sufficient to treat carbide or carbide waste material with carbon monoxide or dioxide, and to get rid of the lime in the usual manner. But in order to obtain pure carbon, mixtures of acetylene and carbon monoxide or carbon dioxide are burnt or exploded under pressure. The reaction then takes place principally, according to the equations $C_2H_2 + CO_2 = 3C + H_2O$ and $2C_2H_2 + CO_2 = 2H_2O + 5C$. Compared with the Hubon process, the Frank-Caro method has the advantage of a larger yield, as not only the carbon contained in the acetylene is separated and obtained, but also that from the carbon monoxide or dioxide, as the case may be. Besides, a combustion takes place, and no simple dissociation. The product is stated to be, therefore, even when large amounts of gas are used, entirely free from tar, and to possess an entirely uniform consistency and deep-black color. The process is also said to allow of the use of larger quantities, for the reason that the end pressure, after ignition has taken place, is considerably less than with pure acetylene, so that vessels of less strength can be used.

*The Utilization of the Nitrogen of the Air.*—At the recent meeting of the International Congress for Applied Chemistry, at Berlin, Dr. A. Frank read a paper on his experiments on the fixation of atmospheric nitrogen, which is published in the *Zeitsch. f. Carbidfabrikation,* June 12. After showing, by statistics, the enormous consumption of nitrogen compounds, Germany alone importing 500,000 tons of niter per year, the author states that fears are entertained whether, on account of this tremendous demand, an exhaustion of the Chili niter beds might not be looked for in appreciable time. He states that investigations by experts have shown that, with the continually increasing demand, such will be the case in thirty years to forty years with the deposits which are now being worked. Under these circumstances, the question of the fixation of the nitrogen of the air will become a very important one. The previous efforts for the solution of the problem are discussed. The present author's investigations dealt with the question of combining the nitrogen with carbides of the alkalies and alkaline earths, especially barium and calcium carbides. Barium carbide was found especially suitable for the manufacture of cyanides, in so far as the combination of the nitrogen with it took place easily. The reaction was $BaC_2 + 2N = Ba(CN)_2$, and the barium cyanide thus obtained could be worked for prussiate of potash and cyan-alkalies with simple methods. Less favorable appeared the behavior of calcium carbide with nitrogen, in so far as, in this case, in spite of a seemingly strong absorption, only a small quantity of cyanide could be found. The interesting fact was, however, ascertained that when nitrogen is absorbed by calcium carbide, there is formed not calcium cyanide, but calcium cyanamide with the separation of one atom of carbon, according to the reaction $CaC_2 + 2N = CaCN_2 + C$. Though the transposition of calcium cyanamide to cyanide can be performed, its low atomic weight, as compared with barium carbide, in so far as 14 parts of calcium carbide are sufficient for the binding of 28 nitrogen, pointed towards a possibility that by means of calcium carbide those nitrogen compounds, which are used for fertilizing purposes, might also be made directly from atmospheric nitrogen. This expectation was confirmed by experiments, which showed that the whole nitrogen of the calcium cyanamide, as well as the cyanamide produced from the latter, could be converted into ammonia by heating with water under high pressure. The reactions taking place were $CaCN_2 + 3H_2O = CaCO_3 + 2NH_3$ and $CN_2H_2 + 3H_2O = 2(NH_4)CO_3$. From these reactions it was deduced that perhaps the raw calcium cyanamide might be used under certain circumstances as a fertilizer, and from a large number of experiments it has been shown that nitrogen under the form of calcium cyanamide, on the different plant cultures, is nearly equivalent to that of an equal amount of nitrogen used in the form of ammonium salts. The percentage of nitrogen contained in calcium cyanamide varies according to the process of manufacture from 14 per cent to 22 per cent, and consequently comes near to that of Chili saltpeter and ammonium sulphate. Cyanamide, on the contrary, and dicyanamide contain 66 per cent of nitrogen, and their behavior with respect to plant nutrition has not been sufficiently investigated, though it is known that cyanamide changes into urea by the simple addition of water. They furnish, however, a valuable starting material for the production of complex nitrogenous compounds; for instance, for the production of creatine by the combination of tarkosine and cyanamide.

*A New Starting Material for the Production of Alkali Cyanides.*—In a paper presented before the recent Congress of Applied Chemistry, in Berlin, Dr. Erlwein, of the firm of Siemens & Halske, Berlin, describes in detail the process of manufacturing cyanides used by the Cyanide Society, under the patents of Frank and Caro. The starting material—calcium carbide—which is used as 75 per cent to 80 per cent product, combines, under the right conditions of the azotizing process, with about 85 per cent to 95 per cent of the theoretical amount of nitrogen. The process proceeds equally well in the muffle as in the electric furnace. There is formed a dark-colored mass of calcium cyanamide, mixed with lime and carbon, which contains about 20 per cent to 35.5 per cent of fixed nitrogen. The transposition of the calcium cyanamide to sodium cyanide, in the further stages of the process, did not present any difficulties. It has also been possible to arrive at the formation of the calcium cyanamide by a direct process in the electric resistance furnace. This is done by starting from a mixture of lime and carbon, thus doing away entirely with the necessity of using carbide. The process is also cheaper than the carbide process. It was further found that the amide of the cyanamide salts could be isolated by a simple lixiviation process in the form of the crystalline dicyandiamide. The reactions, starting from the black cyanamide mass as it comes from the furnace, are represented by the following formulæ: a.—in the lixiviation: $2CaCN_2 + 4H_2O = 2Ca(OH)_2 + 2CNNH_2$. b.—in the melting, where several reactions occur at the same time: $(CNNH_2)_2 + Na_2CO_3 + 2C = 2NaCN + NH_3 + H + 3CO + N$. The potassium or sodium cyanide obtained in this way is a pure white crystalline product, equal to the best in the trade.

## THEORETICAL AND EXPERIMENTAL.

*Rotation of Liquids under the Influence of a Magnetic Field.*—Some years ago Urbasch published in the *Zeit. f. Electro-*

*chemie,* and at more detail in his thesis, a series of experiments tending to prove that, under certain conditions, a rotation of an electrolyte could be effected under the influence of a magnetic field. His apparatus was constructed as shown in the adjoining figure. $P_1$ and $P_2$ are the poles of an electromagnet. T is a small beaker resting on one pole a b of the magnet, while the other pole c d is above the electrolyte under investigation, which is contained in the beaker T. Urbasch found that if

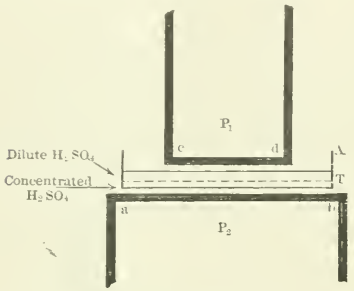



FIG. 3.—ROTATION OF ELECTROLYTES IN A MAGNETIC FIELD.

two electrolytes are arranged in layers, one above the other, in the beaker—for instance, concentrated $H_2SO_4$ and dilute $H_2SO_4$—a rotation of the liquid takes place when it is brought into a strongly magnetic field of an average number of 6,000 to 10,000 gausses or lines of force per sq. cm. This rotation takes place in the opposite direction, when the magnetic field is reversed. Quite a discussion arose over this matter between Urbasch and Professor Drude, of Giessen, the well-known physicist, the latter taking the position that it was absolutely essential to have an electric current in the electrolyte at the same time. If no electric current were present, then there could never be a movement of the solvent, due to the friction of the ions in the latter and produced by the forces, which the magnetic field exerts upon the ions in motion. He states that he repeatedly tried to perform the experiment, but could get no results. Urbasch, on the other hand, upheld the accuracy of his experiments, and finally referred the matter to Professor Nernst. In the *Zeitsch. f. Electrochem.,* June 18, he publishes the latter's answer. Professor Nernst states that on using sulphuric acid and water he observed the rotation quite clearly, without having to heat the electrolyte. The upper pole was not dipped into the liquid, but was arranged quite close to its upper surface. The rotation commenced the instant when the magnetic circuit was closed, and reversed promptly on reversing the magnetizing current. Urbasch gives some precautions to be observed in performing the experiment, and states that the lower pole should have about double the surface of the upper to give the best results.

*Electrochemical Reduction of Aromatic Nitrobodies.*—The preparation of aso and hydraso compounds, as well as benzidines, is often performed by the electrochemical reduction of aromatic nitrobodies in alkaline solution. Elbs proposed to add sodium acetate to the solution in the cathode compartment while a porous cell serves as anode compartment, which is filled with cold, saturated soda solution and contains a sheet of lead acting as anode. The process of reduction in most cases requires a high-current density and, therefore, a small resistance of the bath, in order not to produce too much boiling, on account of too great heating of the electrolyte. It has been ascertained that at times this resistance in the anode compartment increases in a very disturbing manner. Elbs and Stohr investigated this phenomenon, and found, as published in the *Zeit. f. Electrochem.,* June 25, that it is produced by the presence of chlorine in the soda solution or by a deficiency of soda. If the soda is contaminated by any considerable quantities of sodium chloride, the lead anode covers itself with a thick, badly conducting crust of a mixture of lead chloride, lead peroxide and lead carbonate, instead of a thin layer of lead peroxide. Also, if during electrolysis, the anode solution has become contaminated with acetate, which has diffused into it from the cathode compartment and has become poor in soda, the free solution of gas at the anode ceases almost suddenly and the resistance of the bath increases. On continuing the electrolysis, particles of peroxide fall from the anode, and sticking to the pores of the clay diaphragm act there as bipolar electrodes, with the formation of lead peroxide on their side towards the anode, and metallic lead on the side pointing towards the cathode. The authors recommend the following precautions: 1. Use soda free from chlorine, the presence of sodium sulphate does not interfere. 2. Take so much anode solution, that at least 15 cc of cold saturated soda solution are present for every ampere hour to be conducted into the bath.

*Electrolysis of Sulphides of the Alkaline Earths.*—In the course of their investigations on the electrolysis of sulphides, referred to in the Electrochemical Industry, Vol. 1, p. 388, Brochet and Ranson undertook, also, to investigate the electrolytic behaviour of the sulphides of the alkaline earths, and especially of the sulphide of barium. The results of their investigations are published in *Comptes Rendues,* Vol. 136, p. 1195-1197. The experiments were conducted at high temperature, because the sulphide, and especially the hydrate of barium, are soluble with difficulty in the cold. A temperature of 60° to 65° C. is the best for the experiments. The same facts have been ascertained as in the electrolysis of sodium sulphide above referred to, namely, that in a dilute solution there are formed sulphur, sulphite, hyposulphite and sulphate. In the present case, however, most of these products are insoluble and separate at the anode. In concentrated solution sulphur barium hydrate and hydrogen are obtained. The sulphur dissolves in an excess of the sulphide, to form polysulphides, and the barium hydrate stays in solution. Under the conditions of the experiments, the latter has no influence on the sulphur of the polysulphides. The polysulphides are reduced with the formation of sulphuretted hydrogen, which forms the original sulphide again with the barium hydrate. There are thus obtained two inverse reactions, viz.: $Ba.OH.SH + H_2O = BaOH_2 + H_2 + S$. Experiments were conducted with and without diphragms. Anodes of platinum, iron, nickel, carbon, etc., can be utilized, but if the reaction becomes oxidizing for some reason, the carbon is slightly attacked, as is also lead in some cases. Copper acts as soluble anode.

## PRIMARY AND SECONDARY BATTERIES.

*The Thallium Accumulator.*—Thallium as a material for a commercial accumulator probably has very little chance to be used, as it is comparatively expensive, and the electromotive force of the thallium compounds is too small, especially in alkaline solutions. The system, however, is of considerable theoretical interest, as the accumulator consists essentially only of a metal and water. The theoretical interest, therefore, induced L. Jones to undertake an experimental study of the subject, and he publishes his results in the *Zeit. f. Electrochemie,* June 25. The first part of the article treats about the application of Faraday's law, and gives the results of the quantitative analysis of the layers which are deposited on the anode in the electrolysis of thallium hydroxide. In the second part are given measurements of electromotive forces of elements formed of metallic thallium, thallium peroxide, and thallium hydroxide of different concentrations. The latter measurements are compared with the values obtained theoretically by calculation. Measurements of the temperature coefficient of the electromotive force are also given, and its relation to the heat of formation is discussed. When a dilute solution of thallium peroxide is electrolyzed, metallic thallium is deposited at the cathode, and an oxide appears at the anode. If the current is reversed, the deposit of oxide of thallium is

gradually dissolved entirely and the metallic thallium on the cathode also goes into solution. The electrolyses were carried on with an 0.02 n solution, with small sheet platinum electrodes, with a current density of 0.2 to 0.8 mm per sq. cm of anode surface, which was platinized to effect a better adherence to the oxide of thallium. The oxide deposited on the anode was analyzed, and it was found that the oxide, after drying at 200°, corresponds approximately to the formula $Tl_2O_3$, and that the deposited oxide is not a hydrate. The results of the experiments with the test of Faraday's law, and the determination of the reducible oxygen, are still better expressed by the formula $17Tl_2O_3$, $Tl_2O = 4\ (3Tl_2O_3 + Tl_3O_4)$. The author, however, has not made any further investigations, to decide whether this is a definite compound, or whether it is variable according to the anodic current density or the anodic potential, and, therefore, more or less accidental in his experiments. For the discharge of an element consisting of metallic thallium, thallium peroxide and water, respectively, dilute thallium hydroxide solutions, the author formulates reactions, from which he calculates the theoretical value of the capacity of such an element as 235.2, respectively 131.4 amp. hours per kg for $Tl_2O_3$ and Tl (metallic). Marsh (Electrochemical Industry, Vol. 1, page 88) gives the theoretical capacity of $Tl_2O_3$ as 117 amp.-hours per kilo, a value which the author considers wrong. Experimental measurements of the potential were made with three solutions, the first of equal volumes of 1/5 n. thallium nitrate and 1/50 n. sodium hydrate solution free from $CO_2$; the second of 1/5 n. $TlNO_3$ + 1/5 n. NaOH and the third of 1/50 n. $TlNO_3$ + 1/5 n. NaOH. The electromotive forces were measured by the Poggendorf compensation method, the average values at 20° for the first solution at the beginning being 0.6435 volts, for the second, 0.5578 volts, and for the third, 0.6326 volts, the values decreasing in time, owing probably to the oxidation of the thallium hydroxide solution under the influence of the air. The author considers that the values found by experiment and calculation agree satisfactorily, in view of the inconstancy of the cells and the variable potential of the thallium peroxide electrodes.

*The Electromotive Behaviour of the Oxides of Cerium.*—The oxides of cerium are interesting from the fact that Auer von Welsbach has devised an accumulator "consisting of a cerous and ceric electrode." Cerium salts are also used under certain circumstances, as oxygen carriers in the preparation of organic compounds, as, for instance, in the patent of Moest, described in Analysis of Current Electrochemical Patents, Electrochemical Industry, Vol. 1, p. 393. Cerium has three oxides, the cerous oxide $Ce_2O_3$, ceric oxide $CeO_2$, and the peroxide, $CeO_3$, salts of the latter being known only in alkaline solution. By reducing agents they can be reduced to ceric and cerous oxides, which latter is oxidized again by the oxygen of the air. There is, therefore, a possibility of forming a cell, in which there is performed cathodically the oxidation of organic compounds by alkaline ceric solution, and anodically the solution of the cerous compound by the oxygen of the air. In view of these facts, Bauer and Glaessner have undertaken to measure the oxidation and reduction potentials of the cerium salt solutions and publish their results in the *Zeit. f. Electrochem.*, June 25. The measurements were made with a kalomel-electrode with normal-potassium chloride (potential — 0.560 volts) and a Weston standard cell, with a Lippmann capillary electrometer. Potentials were measured in different mixtures of 1/10 molar cerous and ceric sulphate solutions and cerous and ceric nitrate solutions. The latter were found higher than the sulphate potentials. Alkaline cerium solutions and cerium peroxide solutions were also investigated. Hydrogen, carbon monoxide, charcoal, cane sugar, starch, sawdust and organic acids were added to the alkaline solution, and it was found that these, except cane sugar, had no appreciably reducing effect at ordinary temperature. At 70° C., however, hydrogen, carbon monoxide, sawdust, charcoal and ammonia also produced a reducing effect. From cells consisting of a cerous and a ceric solution, with different depolarizers in the cathode and anode solution, the authors draw the conclusion that the probability appears small, that with the employment of watery solutions, elements of this type of practical efficiency could be made.

## GENERAL AND MISCELLANEOUS.

*Electric Power Plant in Livet (France.)*—The Societe Electro-Chimique de la Romanche, as stated in the *Echo des Mines et de la Metallurgie* (abstracted in the *Centralblatt f. Accum. Elem. und Accumobilenkunde*, July 1), has let the contracts for an installation for electric transmission of power obtained from the waterfalls of the river Romanche. The central station in Livet will consist of two triphase alternators with horizontal shaft, direct coupled with turbines at 375 r. p. m. Two triphase transformers, of 2500 kw each, installed near the generators, will increase the voltage from 3500 to 26,000 volts. The exciting current for the generators is furnished by two machines driven by special turbines at 600 r. p. m. The transmission line will be about 35 km long, and will consist of six wires of 8 mm diameter each. Current will be transmitted at 26,000 volts and will be stepped down at the receiving station in Grénoble by two 2500 kw transformers to 5000 volts.

*Ammeter and Voltmeter in Electroplating.*—The importance of the voltmeter and ammeter in electroplating, contrary to the usual practice in the plating shops, has been repeatedly set forth in Electrochemical Industry. An editorial on the subject in *Metal Industry*, June, calls attention again to these facts, and states that it is surprising to find the large number of plating establishments without either voltmeter or ammeter among their equipment, and some even without a rheostat. The reasons why these instruments should be adopted are then explained in popular fashion.

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

### Electric Furnaces and Furnace Products.

*Process of Treating Materials by Radiated Heat in Electric Furnaces.* C. G. P. De Laval, Stockholm, Sweden. Patent No. 729,614, June 2, 1903. Application filed March 19, 1902.

The process under consideration is intended to obviate the losses occuring in electric furnace processes, by reason of the finely powdered raw material being subjected too suddenly to the action of the heat, with the result that a violent generation of gas takes place, which causes the material to be thrown about in the furnace. The inventor proposes to overcome this difficulty, by placing the material in the furnace in such a way that it forms a pile with a sloping side, which is maintained at a practically constant distance from the source of heat, by constantly introducing material at the back of the pile. In this way the pile is continuously pushed forward, corresponding to the melting action of the source of heat upon the surface of the slope. The chemical processes are effected at the surface of the slope, from which gases and vapors escape. The other ingredients of the charge slide down the

slope to the bottom, where they melt. The furnace in which the invention is to be carried out is a simple rectangular construction, with two electrodes introduced a certain distance above the charge, so that the heating takes place mainly by radiation. A reciprocating piston arrangement is described, which is to fill the important function of continuously pushing forward the charge in the proper manner.

*Art of Making Steel Direct From Iron Ore.* M. R. Conley Brooklyn. Patent No. 730,746, June 9, 1903. Application filed January 27, 1902.

The specification describes an improved form of furnace for the production of steel. It is illustrated in the accompanying Fig. 1. It will be seen that its construction is comparatively simple, as it consists essentially of an upper shaft 11, narrowing down to a smaller cross section at the neck 12, and widening out again in the hearth 17. The furnace is constructed of fireclay or suitable masonry, and two transverse heating plates 13 of low electrical conductivity are arranged in the neck. These plates extend entirely through the furnace and are inclined inward, forming thus two walls of the neck. A similar plate 14 is arranged vertically between the plates 13. The surface of the plates are preferably protected by some refractory material such as magnesite or dolomite, so that they are not attacked and too rapidly consumed. All the plates are reduced in area where they extend across the neck of the furnace, so as to get more resistance into the central part of the plates, and to get most of the heating effect there. The inventor states that he has found experimentally that the best material for the plates is a mixture of approximately 75 per cent. fireclay and 25 per cent. plumbago. In addition to these upper electrodes there is placed a band 18 of similar material around the hearth of the furnace, which is protected in its turn by a coating 19. The hearth is also provided with a tap holt 20 to draw off the melted material. For the operation of the furnace the ore is crushed and enough carbon is mixed with it to combine with the oxygen, with preferably a slight excess, so that the ore will contain about 1 per cent. or less of carbon.

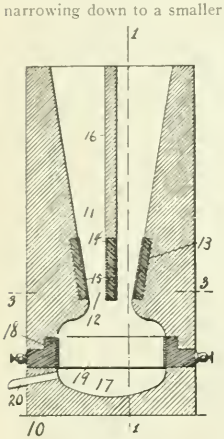


FIG. 1.—CONLEY FURNACE.

*Manufacture of Silicon and Aluminium From Silicates of Alumina.* C. H. Homan, Christiania, Norway. Patent No. 732,410, June 30, 1903. Application filed October 13, 1902.

The process consists in heating silicate of alumina, for instance, common clay, in an electric or other high temperature furnace with a reducing agent, in such quantity that the silicic acid and certain bases—for instance $Fe_2O_3$—are reduced, while the oxide of aluminium remains unreduced. The product of this reducing process will be silicon, together with the metals of the respective bases, and a slag of substantially oxide of aluminium. If other silicon products are to be obtained, for instance ferrosilicon, the reduced silicon may be tapped out at different stages of the process, thus furnishing at one stage of the process pure silicon and at another stage ferrosilicon. Metallic aluminium is by preference used as a reducing agent, and during the smelting process it combines with the oxygen from the silicic acid and from the reducible bases. The slag therefore consists of the oxide of aluminium thus formed, together with the oxide of aluminium from the silicate, and small quantities from the reducible bases, such as lime, magnesia and alkalies. The reduction of the silicate by aluminium is stated to begin at temperatures not very far above the melting point of aluminium. The object of raising the temperature to such a high degree is stated to be for the purpose of intensifying the reaction, in order to reduce all the silicon and keep the alumina slag melted, so as to separate it completely from the silicon. The working temperature of the furnace is said to be most practically placed at about 4500° F. For 100 parts of a clay consisting of $SiO_2$ 47 per cent., $Al_2O_3$ 38 per cent., $Fe_2O_3$ 3 per cent., MgO 0.25 per cent., $K_2O$ 0.25 per cent. and $H_2O$ 13.5 per cent., by weight, there are taken 28.6 parts of aluminium.

### Apparatus and Processes for the Electrolytic Production of Metals and Compounds.

*Electrode.* James Hargreaves, J. W. Stubbs and J. Kearsley, Middlewitch, England. Patent No. 731,453, June 23, 1903. Application filed November 8, 1902.

This application describes a peculiar construction of anodes or electrodes, consisting partly of carbon for use in electrolytic cells. and probably designed more particularly to be used in Mr. Hargreaves' own apparatus. The object in constructing it has been to get an electrode which offers little resistance to the electric current and the parts of which may be readily renewed when worn or broken. The construction is illustrated in central vertical cross-section in Fig. 2. It consists of a bar of metal 2, connected to the source of electricity. The bar may be made of two strips riveted together in such a way as to form openings 3 at intervals, or these openings may be worked out in a solid bar. Passing through these openings, but not fitting closely into them, are nipples or bars of carbon. In order to make electric contact between the bar and nipples 4 melted lead or another suitable metal is cast into the openings 3 between the bar and the nipples. This also holds the nipples firmly in position. In order to still further reduce the resistance and improve the contact, indentations or perforations 6 may be arranged into or through the nipples 4, which are also filled with melted lead. The bar 2 and 5 are then preferably coated with tar pitch or similar impervious insulating material, after which they are covered with Portland cement or any other insulating compound. The coating or impervious material prevents the access of the electrolyte to the metal bar 2 and its corrosion. The ends of the nipples project through the cement covering and are fitted closely into openings 8 in the blocks or pieces 9 of gas or retort carbon, from which the current passes into the electrolyte. The extremities of the nipples are covered with cement or similar material 10, to prevent wearing at those points. The nipples may also be covered with sheaths 11 of insulating material, in order to further protect them.

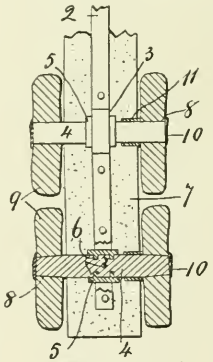


FIG. 2.—HARGREAVES ELECTRODE.

*Electrodeposited Lead.* A. G. Betts, Lansingburg, N. Y. Re-issued patent No. 12,117, June 9, 1903. Original No. 713,278, November 11, 1902. Application for re-issue filed April 22, 1903.

The specification is identical with that of No. 713,278, which see in Electrochemical Industry, Vol. 1, page 133.

*Method of Applying Heat to Electrolytes.* C. F. Burgess and C. Hambuechen, Madison, Wis. Patent No. 732,616, June 30, 1903. Application filed March 12, 1903.

The method of heating the electrolyte as described in the

present specification, consists in employing one or both of the electrodes as heaters. For this purpose they are connected in a separate circuit of low voltage, not exceeding 5 to 10 volts for good conducting electrolytes. A higher pressure may, however, be used with electrolytes of relatively high resistance. The heating current is preferably an alternating one, and derived from the low pressure secondary of a transformer. As practical application of the method the inventors cite the case of the electrolysis of fused caustic soda for the production of metallic sodium. The apparatus described in this connection is illustrated in Fig. 3. In this case both electrodes are shown as being heated, and the inventors state that they have found it desirable, that the electrolyte be maintained at a higher temperature around the anode than around the cathode. The electrodes are designated by numbers 9 and 10,

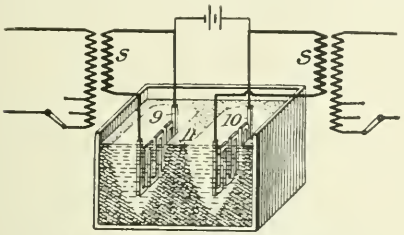



FIG. 3. APPARATUS FOR HEATING ELECTROLYTES.

and can be readily heated by means of the low pressure current derived from the secondaries *ss* of independent transformers. It is stated that the temperature may be so regulated as to maintain in a fused electrolyte between the electrodes a semi-solid, though conducting, diaphragm, which has the composition of the electrolyte, and constitutes an efficient separator for the products of electrolysis. This diaphragm is indicated by 11. It is stated that the method may be employed in all deposition processes, wherein the character of the deposited metal depends upon the temperature at the cathode or where the corrosion of the anode is influenced by the temperature. For metals like calcium, barium, strontium and magnesium, for the electrolytic production of which a high temperature at the cathode is required, the method may also prove useful. The inventors also state that experiments have demonstrated that the method can be used with advantage in regulating the oxidizing and reducing processes at the electrodes in organic work. The method of heating described in the specification includes those cases where one or both of the electrodes or a part of them is included in the heating circuit, and those, where the heated portion is only in physical or electrical contact with the electrode, and the electrode heated by transmission.

### Storage Batteries.

*Method of Producing Electrodes for Electric Accumulators.* E. W. Jungner, Stockholm, Sweden. Patent No. 731,308, June 16, 1903. Application filed August 5, 1901.

The specification outlines a method for the electrochemical corrosion of metallic surfaces, for the purpose of considerably increasing their surfaces and thus render them suitable to serve as a carrier for active masses, that possess little or no conductivity. The metallic surface to be corroded is arranged as anode in an electrolyte composed of an alkaline solution to which is added a salt, the acid radicle of which forms with the metal a soluble salt. In order to produce such a corroded surface, it is necessary that the metal combination formed should not be soluble with such great difficulty as to form a layer and thus to prevent further decomposition of the plate, and it should not be soluble to such a degree that it is dissolved by the electrolyte as soon as formed. Therefore, it is only necessary that the formation of the metal combination should be more rapid than its solution in the electrolyte. The inventor describes the following practical application of his method. If a plate of pure nickel is placed in a solution of chloride of sodium as anode, it is uniformly attacked, as soluble chloride of nickel is produced. If it be thus placed as anode in a concentrated solution of an alkaline hydrate, a thin layer of insoluble oxide of nickel is formed on the surface. If, on the other hand, the chloride of sodium and the alkali solutions are mixed in certain proportions, according to the density of current, temperature, etc., oxychlorides of nickel of various composition are formed on the surface of the plate, especially if the surface has previously been rubbed with a fine emery paper. If the electrode now is placed as anode in a 20 to 30 per cent. alkaline solution from six to eight hours, and with a current of about 1 amp. per sq. dm., the layer of oxychloride of nickel next to the metal will be transformed by and by into a high oxygen compound of nickel. If the layer formed in this manner on a nickel plate is removed, for instance, by quickly plunging the plate into hydrochloric acid, its greatest porosity can be distinctly seen. If the plate is then amalgamated and placed as a cathode in a solution of alkali zincate, it is capable of receiving a considerable quantity of zinc, which will adhere to it. The inventor states that other metallic plates can be prepared in a similar way for use as support for an active mass in storage batteries with an alkaline electrolyte. This is said to be especially true for copper, cadmium and iron, with suitable modifications and changes of the nature, concentration and temperature of the electrolyte, the density of current, etc.

*Storage Battery.* Carlo Bruno, Rome, Italy. Patent No. 731,429, June 23, 1903. Application filed December 4, 1899.

For the electrodes of his storage battery the inventor provides a very thin conducting plate of lead (of less than one-tenth of a millimeter in thickness), by rolling and stamping out of the plate itself, upon one or both sides, projections at right angles to the plate. It is important that this should be effected by stamping, for by pressing or casting, these extremely fine projections would break off and remain in the wooden molds. That the projections should be perpendicular to the plate is stated to be still more important, as by this means the inventor claims to be able, without any danger of bending the projections, to apply the active mass, which had previously been rolled or otherwise suitably formed into sheets, laterally to the metal plate, in such a manner that an endless strip of the mass is passed upon an endless strip of the lead plate, and the whole then cut into plates of suitable length. The suspension of these thin plates is effected by the employment of a pocket or casing of celluloid or similar material, perforated in the usual manner, which casing is suspended upon transverse strips.

*Process of Constructing Storage Battery Plates.* G. H. Gale, Detroit. Patent No. 731,447, June 23, 1903. Application filed May 16, 1902.

The plates described in the specification are made of metallic lead and provided with a series of holes extending through the plates. The walls of these holes are reamed out in the interior of the plate in such a manner as to make them communicate in the interior of the plate. There are a series of webs and interior strengthening ribs provided. The space thus reamed out in the interior of the plate and the holes are filled with active material. The inventor claims that such a plate will not only hold a larger amount of active material, but will hold it in such a manner that it will not fall out or become displaced.

### Galvanic Cells.

*Primary Battery.* J. W. Gladstone, West Orange, N. J. Patent No. 730,014, June 2, 1903. Application filed December 17, 1902.

The object of this invention is to secure simplicity and compactness in that class of voltaic batteries in which the nega-

tive electrode consists of a plate comprising oxide of copper or another depolarizing agent, properly molded and agglomerated. Another object is to improve the internal conductivity of the battery by means of extended contact surfaces between the parts which sustain those plates and the plates themselves, and also to facilitate the cleaning of the parts which make contact with the plate. A detailed mechanical construction to accomplish those various objects is given and illustrated in the specification. The inventor produces his copper oxide plates by mixing the copper oxide with a slight amount of alkaline water and forming it into plates, and he then hardens the plates by exposing them to a red heat, until the parts are well baked together.

*Battery-Jar.* G. H. Condict, New York. Patent No. 729,550. June 2, 1903. Application filed December 16, 1898.

The specification describes a construction consisting of a battery tray or container, in which are arranged a number of battery jars. The latter are arranged as close together as possible in such a manner that they cannot move, which is brought about by providing them with a number of ribs on the outside. Spaces are thus formed so that any liquid which escapes over the top of the jars can run down. An alternative construction is shown in which the ribs are dispensed with, and a separation of the upper edges of the individual jars is secured by cutting their upper parts slanting on the outside. The arrangement is adapted to be placed on an electric car or vehicle, and for such purposes is constructed of rubber or vulcanite.

*Solution for Primary Batteries.*—Harry S. Amwake, Camden, N. J. Patent No. 729,833, June 2, 1903. Application filed May 22, 1900.

The inventor prepares two solutions as follows: One solution of seven parts of sodium hydrate and ten parts of water by weight and another of five parts of sodium bichromate, nine parts sulphuric acid and ten parts water by weight. These solutions are to be used in such primary batteries as are constructed with porous porcelain divisions, the sodium hydrate solution being placed inside the porous porcelain plates and the sodium bichromate solution in their outside. The two mixtures, says the inventor, will unite and combine by gradual percolation through the porous plates and an energy developed which greatly increases the voltage of the battery.

*Battery.* D. H. Wilson, Chicago. Patent No. 729,827, June 2, 1903. Application filed April 30, 1902.

The cell consists of an outer jar, preferably with an opening at the bottom, within which is arranged a carbon electrode of annular form, so constructed that it forms a central compartment and an annular one surrounding the first. The inner compartment contains a depolarizing solution, while the outer compartment contains the battery solution. A second electrode, preferably of zinc, is placed in the outer compartment, resting on a suitable insulating piece on the bottom, it being thus separated from the carbon. The carbon electrode is provided with a piece on the bottom, which projects through an opening in the containing jar. This projection is fitted with a metal bushing, to which is connected a conductor, leading to a binding post. By this arrangement the inventor claims to overcome the corroding of the binding posts, etc., arising from the creeping up of the salts of the batteries.

*Galvanic Battery.* J. R. Lord, Tottenville, N. Y. Patent No. 730,833, June 9, 1903. Application filed February 20, 1903.

The inventor states that the process consists in the evaporation of the exhausted electrolyte of a galvanic element into a condenser, the apparatus being closed so that none of the factors composing the electrolyte escape. When the evaporation is completed, the condenser is supposed to contain the water and the acid employed, and the positive and the negative electrodes plus the oxide on one or both of them remain behind. The electrodes are thus said to be left in a condition ready for the addition of an electrolyte to render them active, and when the acid and water contained in the condenser are allowed to enter the cell again, the generation of electricity can be resumed. The inventor modestly states that his invention relates to electrochemistry, and is applicable in the broadest and most general sense.

## Miscellaneous.

*Apparatus for the Generation and Direct Electrolytic Application of Electric Currents.* F. E. Elmore, London, Eng. Patent No. 726,659, April 28, 1903. Application filed January 10, 1902.

The invention relates to an apparatus of the unipolar dynamo type for generating large currents and applying them directly to electrolysis. The inventor states that the chief objects of the invention are to overcome, in a great measure, the difficulties hitherto attending the collection and distribution of large currents, and to obtain electro deposits rapidly and economically. The apparatus is illustrated in Fig. 4 in half vertical section. A is a vertical shaft driven by bevel

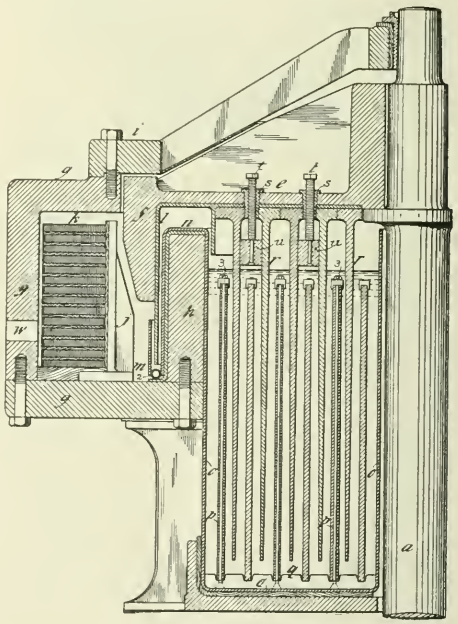


FIG. 4.—ELMORE APPARATUS.

bearing, and its lower end extends as a plunger into a hydraulic cylinder. On the upper part of the shaft A is fixed an iron disk *e*, having at its periphery a deep flange *f*, which may be termed the armature. This armature extends down into the interior of the cylindrical electromagnet, having a base outer and upper side *g*, and an inner side *h*; also a cover *i*, which is the periphery of a frame carrying the upper bearing, for the shaft *a j* is a cylindrical shell of non-magnetic material lined externally with insulating material, on which are wound a number of coils *k*, of insulated hoop, each coil separated from the next above it by a layer of insulating material. To the flange *f* is attached a cylindrical shell *l* of good conducting material, such as copper, the edge of which dips into a trough *m* containing a fluid conducting material, preferably an alloy of lead and mercury, the fluidity of which is assured by a steam pipe 2 at the bottom of the trough. The shell *l* continues as a lining on the under side of the disk *e*, and the one side *n* of the trough *m*, which is insulated from *h*, turns over it and extends down to form the sides *o* and bottom of a

cylindrical tank or shell having its bottom resting on the base of the apparatus. The tank *o* is of metal such as lead, which is not attacked by the electrolyte. From the bottom of the tank *o* extends upward a number of anodes, each in the form of a cylindrical shell *p* held in position by long bolts 3, passing through it at intervals and fixing it in a groove in a lead disk *q* at the bottom. To the lining *l* of the disk *e* are attached a number of cathodes *r*, each in the form of a cylindrical shell, tapering in thickness, so as to be thinner at the lower end than at the top. They are fixed to the disk *e* by screwed sleeves *s*, through which pass setting screws *t*, the ends of which are reduced in diameter and pass through holes in annular blocks *u*, in which they can turn. The apparatus is said to operate as follows: The magnet *gh* being excited by a current of electricity traversing the coils *k*, and the shaft *a* with the disk *e*, and the cathodes *r* being revolved, while the tank or cell *o* is charged with a suitable electrolyte, a large electric current is generated, which passes from *f* through the alloy in *m* to the cell *o* and its bottom, thence along the anodes *p* and through the electrolyte to the cathodes *r*, thence back to *f*, the result being that the metal of the anodes *p* is rapidly dissolved and deposited on the cathodes. When desired, the cover *i* can be unscrewed, the shaft can be raised by applying pressure in the hydraulic cylinder, raising with it the disk *e* and the cathodes *r* with the metal deposited on them, which can be pushed off them by means of the screw *t*. The revolving ribs of the disk *e* act as the blades of a fan, causing currents of air to pass through the air spaces of the magnet and between its coils to outlets *w*, thus keeping the coils cool.

*Electrode.* W. R. Chipman, New York. Patent No. 732,047, June 30, 1903. Application filed May 8, 1902.

The invention relates to a peculiar composition of an anode which is to be used in an apparatus for purifying liquids, by means of the production of oxyhydrates. The electrode is composed of metallic aluminium, Straits tin and nickel. The aluminium is stated to be the oxyhydrate developing element, the Straits tin the binding element, and the nickel the hardening element. Different liquids demand different proportions of these elements, but the inventor has determined upon a composition which is particularly effective in the purification of water. Such composition is substantially as follows: Aluminium, 35 to 40 parts; Straits tin, 50 to 45 parts, and nickel or other suitable hardening substance, 15 parts. With these elements a suitable flux is used, consisting preferably of crude tartar and saltpeter in equal parts, green bottle glass two parts, and calcium borax one part. The flux is especially suggested to render the aluminium element of the composition completely fluid. In place of the nickel as hardening element the inventor states that he may use ferrosilicon, chromium, ferro manganese or platinum (?). "In order to properly effect the compounding of the ingredients of my composition, the aluminium should be first reduced to a liquid state. Then the hardener should be added and the flux employed to keep the mass fluid. When ready to manipulate the composition for the desired purpose, the Straits tin should be added slowly, the mass being kept well agitated. The compound thus formed will be found to be malleable and capable of being easily cast or rolled into shape to be used as anode." An anode of the above composition is stated to produce oxyhydrates, the action of which is to form with the nitrogenous matter in solution or suspension in the liquids to be purified, a coagulum which is easily filtered out, thus leaving the liquid pure.

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The Electrochemist and Metallurgist, which was published by Messrs. Sherard Cowper-Coles & Co., of London, and the last number of which appeared in May, 1902, is to be reissued as the official organ of the Faraday Society. The papers presented to the Faraday Society and the discussions of these papers will be printed in full in this journal. The first number of the new series is to be issued shortly.

## CURRENT NOTES.

Fall Meeting of the American Electrochemical Society.—At the last meeting of the Board of Directors, held at Philadelphia on June 13, it was decided to hold the next general meeting at Niagara Falls, September 17, 18, 19, 1903.

Bibliography of Metallic Alloys.—We have received a reprint of a paper by Dr. M. Sack, giving a list of the literature on metallic alloys. The list has evidently been compared with the greatest care, and appears to be complete; its compilation has certainly required an enormous amount of work. The list comprises not less than 880 articles. First a list of the titles of the articles is given, arranged alphabetically according to the authors, with reference to the journals in which they were originally published or afterwards reprinted or abstracted; a very brief and concise statement is added of the special alloys which are dealt with in each article. A second list is arranged alphabetically according to the metals contained in the alloys. The list was first published in the *Zeitschrift f. Anorganische Chem.*, v. 35, p. 249-328.

Training of Engineers.—At the recent Toronto Convention of the Canadian Electrical Association, Mr. P. M. Lincoln, of the Westinghouse Electrical & Manufacturing Co., read an interesting paper on "The Training of the High Tension Engineer." The general remarks made by Mr. Lincoln on the training of high tension engineers may also be applied to that of electrochemical engineers: "There are two schools in which the electrical engineer *may* receive his training, but only one in which he *must* receive a course before he can be called an engineer. Those things which are learned in the schools equipped with professors and laboratories and mathematical text books must be supplemented by the things which can be learned only in the school of experience. These two schools are quite different in method. The college instructs in theory, and in those methods of doing things which have become standard by universal adoption. The college teaches positive knowledge. In the school of experience, on the other hand, one is more apt to learn how *not* to do it, and by the elimination of the unsuccessful, arrive at the goal of success. The knowledge gained by experience is more often negative. * * * * * The engineer, no less than the man in any other department of human endeavor, may find in failure the way to better things. It was Roosevelt, the strenuous, who gave expression to the sentiment that absence of failure accompanied only lack of effort. The uses of adversity are sweet, and the engineer may well heed the words that Shakespeare puts into the mouth of the Duke, who, exiled to the forest of Arden, finds tongues in trees, books in running brooks, sermons in stones, and good in everything." Among the examples of the differences between theoretical knowledge and practical high tension experience the author mentions that the man fresh from the college laboratory enters his practical duties with the idea that rubber is one of the best insulators that exists. It is not until he has seen rubber insulation break down in the most unaccountable manner that he finds that rubber as a high tension insulator is extremely treacherous. The deterioration of rubber insulation is probably due to chemical reactions on the rubber induced by the brush discharges, which are in turn caused by the high voltage of the conductor." To find a perfect insulating material should be an interesting and promising subject for electrochemical researches. Concerning the value of university training the author speaks as follows: "I look back upon my own course in electrical engineering, and feel that it is the most valuable asset I ever possessed. The technical course is the best of foundations, but it is only a foundation. The end of the college course is rightly called Commencement. The great advantage of the technical education is that it gives the man proper equipment for overcoming the difficulties with which his experience is bound to bring him into contact. It gives him, as nothing else will, the power of initiative—that most valu-

able quality that an engineer can possess. There is nothing like the college education to equip a man for making every accident a lesson in how not to do it, and every failure a stepping-stone to success."

## BOOK REVIEWS.

A Text-Book of Organic Chemistry. By Dr. A. F. Holleman, translated from the second Dutch edition by A. J. Walker, Ph. D., New York: John Wiley & Sons. Price $2.50.

As was stated in our notice of Holleman's Inorganic Chemistry (Electrochemical Industry, June, 1903, p. 362), this author has endeavored specially to apply the underlying principles of the newer physical chemistry to the explanation of the phenomena and reactions of chemistry. How fully this plan was carried through was indicated in our notice of the inorganic volume. In this second, or organic volume, the same plan is followed, although the illustrations are of a somewhat different character, and electrochemical phenomena are not so frequently brought to our attention. The physical methods of determining molecular weight and constitution assume, however, great importance, and are well presented.

Many organic reactions are explained, as was the case in the author's discussion of inorganic compounds, on the theory of hydrolytic dissociation. Thus, on page 110, the cleansing power of soap is claimed to be mainly due to the presence of free alkali in the dilute soap solution. The author shows that, in concentrated soap solutions, a very slight color only is produced with phenol-phthalein, while the addition of a large quantity of water causes the development of the red color due to the action of the base liberated by dissociation. The author shows on pages 112 and 113 how Ostwald's *law of dilution* explains the differences of strength in the monobasic organic acids of the fatty series.

Very interesting and satisfactory statements are given of the direct hydrogenation of acetylene in the production of hydrocarbons corresponding to those found in American and Caucasian petroleum (p. 155); of the conditions for the electrolytic formation of iodoform (p. 175); of the electro-reduction of uric acid, caffeine, xanthine and other purine deviations (p. 334); and of the indigo synthesis now in use by the Badische Aniline and Soda Fabrik.

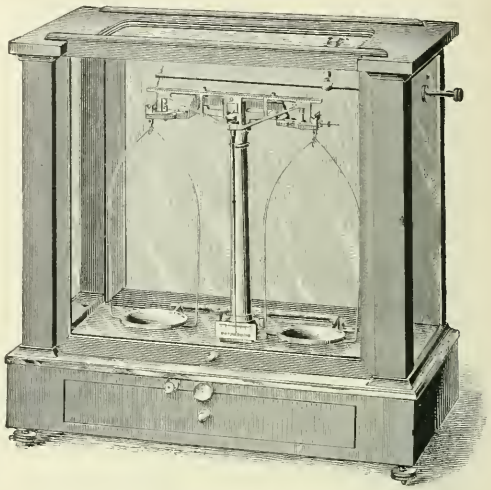
The theoretical discussions of some of the newer discoveries of organic chemistry are also presented by the author in a very interesting way. Thus, on page 193, we have a very full and satisfactory account of the malonic acid synthesis and its importance in synthetic organic work; on pages 279 and 281 of the theory of the inversion of sugars and the action of enzymes in fermentative decompositions of the same class of bodies; on page 304 of the theory of oxonium salts and the tetravalency of the oxygen atom; and on page 442 on the methods for the determination of position for meta and para compounds.

Of course the Holleman book is not a descriptive or encyclopædic handbook. It is a text-book, in which the theory is presented with just sufficient description of organic compounds to illustrate the classification. From this point of view it is an excellent work and full of suggestion.

S. P. Sadtler.

## ANALYTICAL BALANCE.

The accompanying illustration shows an analytical balance, made by Mr. Herman Kohlbusch, of New York City, with aluminium beam, for a charge up to 200 grams; sensitive to 1-20 milligram. It is contained in a mahogany glass case, with front and back sliding doors and glass top, the entire balance being fitted on plate glass. The rider has a clean sweep across the beam, which is graduated on both sides; the space between the bows is 4 ins., which may be increased, if desired. All bearings are agate planes with agate knives. All parts are heavily plated with platinum, which makes the balance non-corrosive throughout. The balance is supplied with apparatus for specific gravity and a stand for weighing tubes.



ANALYTICAL BALANCE.

## THE CHEMICAL INDUSTRY IN GERMANY.

From a recent consular report of Mr. Ernest L. Harris we gather the following information on the chemical industries of the German Empire. The statistics for the year 1901 placed the number of chemical establishments at 10,385, which gave employment to some 150,000 workmen. The growth of this industry is apparent from the fact that the number of chemical establishments in Germany in 1894 was 5,758, with 110,348 workmen. Concerning electrochemical processes, it is mentioned that caustic potash is produced principally by means of electrolysis; it is a specialty of the Elektron Chemical Works, situated at Griesheim, near Frankfort. In the spring of 1901, these great chemical works were almost totally destroyed by fire, which was attended by great loss of life. They have since been rebuilt or are in process of construction. In 1900 the total exports amounted to 15,379 tons, valued at $1,475,000. Chloride of lime is also made in "immense quantities" by the Elektron Works.

In the manufacture of aniline colors, Germany holds a commanding position. Raw materials, such as coal tar and aniline oil, are imported from England; in the manufacture of aniline colors, their former value is increased fifty fold. Nearly every country in the world is dependent upon Germany for aniline colors.

Germany exports each year about 3000 tons of drugs, worth $4,000,000, and imports about half this amount. Great Britain and the United States are in this line, as in a great many others, Germany's best customers.

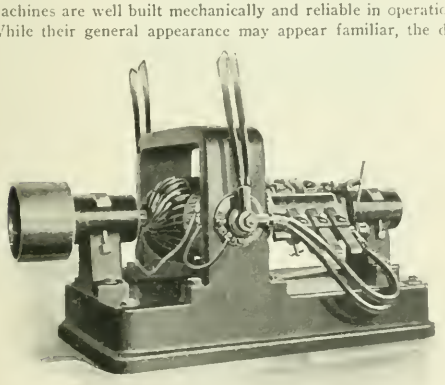
Among the leading chemical factories in Germany are the following: Badische Anilin and Soda Fabrik, in Ludwigshafen-on-the-Rhine; founded in 1865, it now employs 6000 workmen and 300 officials. The chief articles of manufacture are artificial dyestuffs, aniline, and aniline oil and salts; indigo is produced on a large scale by a synthetic process; alizarin colors and strong sulphuric acid are also made. Farbenfabrik, vormals F. Bayer & Co., in Elberfeld; it employs 5200 workmen, 27 engineers, 148 technical advisers, 520 mercantile clerks, and 145 trained chemists; the chief products of manufacture are drugs and aniline, and alizarin colors. Farbwerke, vor-

mals Meister, Lucius & Bruening, Hoechst-on-the-Main; established in 1862, they now employ 5000 people in the manufacture of tar colors, indigo, and all kinds of durgs. Seventy-seven German chemical plants exhibited their products at the Paris Exposition in 1900.

The consular report is concluded by the following remarks: The German chemical industry, like the textile industry, is absolutely dependent upon the unrestricted importation of raw materials and the exportation of products manufactured therefrom. Germany exports about $14,000,000 worth of chemicals, colors, dyes and drugs to the United States every year. The above description will show the importance of this industry to a great class of the German people. The time has arrived for us to put forth every effort to develop our own chemical industry, so that we shall become practically independent of German imports. The workmen in the German chemical factories earn good wages. The industries, on the whole, are prosperous, many companies paying 10 and 12 per cent. dividends. In spite of the secrets used in the German industry, especially in aniline colors, which are transmitted from generation to generation, our tariff has forced many German manufacturers to establish branches in the United States in order to keep a grip on their trade. The raw materials necessary can be procured as well by us as by Germany. Our universities are taking more interest in the subject every year. The chemical industries of the United States ought soon to be able to compete successfully with those of Germany in the markets of the world.

## DYNAMOS FOR ELECTROCHEMICAL WORK.

A new line of electrolytic generators for electroplating, electrotyping and other kinds of electrolytic work requiring a low voltage and a heavy current, has been placed on the market by Mr. Chas. J. Bogue, 207 Centre Street, New York City. The machines are well built mechanically and reliable in operation While their general appearance may appear familiar, the designer has succeeded in such a careful redistribution of material that the weight of the machine per watt of output is smaller than in former types.



DYNAMO FOR ELECTROCHEMICAL WORK.

The machines are made in nine different sizes: P 1, 2, 3, 4, as bipolar and P 5, 6, 7, 8, 9, as multi-polar machines, to give currents from 100 to 3,600 amperes. The accompanying illustration shows one of the smaller sizes, giving about 500 amperes.

P 1 is the smallest size, giving normally 100 amperes at 5 volts; it may, however, be wound for any voltage between 2 and 30. In a recent test of such a machine, up to 155 amperes were taken from it, the number of revolutions per minute being 1,600. The voltage which was 5.5 at no load, dropped to 4.75 at 155 amperes. P 4 is normally rated to give 410 amperes at 5 volts. A machine of this type was recently tested up to 550 amperes, the number of revolutions per minute being 1,300. The voltage dropped from 5.5 volts at no load to 4.75 volts at 550 amperes.

The machines have been designed under the supervision of an engineer who has a very intimate acquaintance with the requirements of electroplating shops. The machines are guaranteed to run at 50 per cent. overload without excessive heating.

## HEATING AND VENTILATING SHOPS.

Of all matters constantly coming before engineers, the subject of heating and ventilating shops is generally least understood. The chief cause of this state of affairs is the fact that the proper installation of a heating and ventilating system requires not only a knowledge of the physical and thermal principles involved, but also an extensive and almost exceptional experience in their application.

At a recent meeting of the New York Railway Club an interesting discussion took place on this subject. The problem of effectively distributing heat and air in large one-story buildings is difficult on account of the large amount of roof, wall and window surface, the loss of heat being very great; there is also a tendency toward unequal distribution of the heat, the warm air rising to the roof and the cold air flowing to the floor, where it renders the workmen uncomfortable. It is important, then, not only that sufficient quantity of heat should be delivered to the building, but also that it should be delivered where it will do the most good.

The direct system of heating by steam or hot-water coils is falling into disfavor for the reasons indicated above, and is being superseded by the fan or hot-blast system. The apparatus required for the latter consists usually of a steam coil for heating the air, an engine or motor-driven fan for propelling the air through the heater and to its destination in the shop, and a system of piping or ducts leading it where it is needed. The heater will contain a considerable less length of pipe than would be required for direct heating, due to the higher velocity of the air over the pipe surfaces. The blower is additional equipment, but its use would be justified on the score of ventilation alone, something which is hardly considered at all in the direct system of heating. The exhaust of the engine is usually turned into the heater, thus obviating any loss from that source.

The distribution of the air by means of pipes should be so carried out that the lower part of the room is kept at a comfortable temperature, while at the same time no disagreeable drafts are produced It has been found that by properly proportioning and directing the delivery flues most satisfactory results can be secured. Illustrating this point some very interesting examples were cited, at the meeting mentioned above, by Mr. C. H. Gifford, of the B. F. Sturtevant Co., of Boston, Mass. He pointed out that, in the first place, if one desires air or almost any other form of gas or substance at any particular place at any particular time, the best way is to provide a suitable conduit to deliver it there, and, if there is any difficulty, which there may be, by air blowing on an individual workman, it is a simple mechanical detail to rectify it, and, if one is unable to predetermine where the men or machines are to be located in a building, one can simply have an adjustable discharge opening from the pipe delivering the air. If, per chance, it blows upon someone there generally is some space near the person to which the air can be directed, and therefore cause no inconvenience whatever.

As an example of what can be accomplished by distribution, Mr. Gifford referred to the machine shop of the New York Shipbuilding Company. They have a building, about 1100 ft long, 250 ft. wide and 82 ft. high. The proposition was to heat one-half of this building and leave the balance of it unheated To solve this problem they conceived the idea that there could be a partition put across the middle of the building about 12 ft. high, and they could then bring the heated air down to the zone

which it was desired to heat, which was not over 8 ft. above the floor. In that way they expected to confine the air in the space.

It was something of a speculation and rather a bold attempt, but it was done. The apparatus is arranged under the landing platforms of the gallery which surrounds the shop, so that it is out of the way of the cranes. Pipes are carried along beneath the runway of the cranes and branches are brought down on the posts and discharge the air toward the floor, the outlet being in the form of a Y, which is adjustable.

This arrangement performed just what it was expected to do; it is surprising to note the difference in temperature between the two sides of that partition; it is almost the same as when one passes from the building out of doors. The result is simply due to the fact that the air was brought down and continually pressed down into the space which it was desired to heat.

Further emphasizing the advantages of correct distribution. Mr. Gifford says that it is possible in some cases to introduce $50 worth of additional pipe to carry the air where it is most needed, so that one can, on account of this, leave out $100 worth of heating apparatus; that is, one can get equal results by using smaller apparatus and less steam.

The adoption of the fan system renders the control of the heating apparatus, and of the ventilation ideal. During very cold weather, or in the morning when the building is being heated up, the air supply may be drawn from within the building itself, thus effecting a great economy of heat. In some buildings having a very high cubic space per occupant, sufficient ventilation during the winter time will be supplied by the leakage of air through doors and crevices about the windows, by transfusion, etc.

According to Mr. E. T. Child, also of the Sturtevant Company, the advantages of the system are: Convenience in handling, since the entire heating system of a building may be controlled from one point; efficiency and economy, by controlling the speed of the fan and reducing the length of pipe to which steam is supplied, leaving more steam available for other purposes; the fact that the entire heater coil is in a steel housing, makes the danger from fire much less than with many pipes passing through partitions of wood.

In the summer time this system gives the opportunity to ventilate the shops. This is quite important. Some shops are very apt to become overheated in the summer time, and a current of cold air may be drawn from a basement making them much more habitable. The pipes should be so arranged that the air will not be discharged directly upon the workmen. If the space around the walls of a building is properly heated, one may never worry about the centre, as that will keep warm.

They have found, therefore, the most satisfactory heating will result from numerous pipes discharging on the outside walls at a point about 6 ft. to 8 ft. above, and directed toward, the floor. These pipes should be located from 25 ft. to 40 ft. apart, depending upon the character of the building. This arrangement causes hot air to be blown downward, whence it spreads on the floor, keeping it warm before the air has a chance to follow its natural tendency and ascend to the roof. Hot air has a very bad faculty of getting up in the trusses, and if one blows the air directly at the floor and gets the floor warm, at the same time keeping the outside of the building warm, the problem is practically solved. In the case of an underground duct, it is well to use short outlet pieces which will discharge the air along the walls at the floor.

## SPINTHARISCOPE.

The spinthariscope is an instrument recently invented by Sir William Crooks to enable one to observe the discharge of radiant matter from radium. Two forms of the instrument are now being put on the market by Messrs. Williams, Brown & Earle, of Philadelphia; they are shown in the adjoining illustration.

The rays or corpuscles which are being continuously given out by radium are rendered visible when they strike a fluorescent screen. The spinthariscope slide, shown in the upper part of the figure, is in the form of a microscopic slide, and is intended to be examined under the microscope, with an objective of about 1½-in. power. The spinthariscope tube shown below is a complete instrument for pocket use, and consists of a tube about 1½ ins. long, with a fluorescent screen at one end, a movable pointer carrying the radium being placed over it, and above them a powerful lens contained in a sliding tube. The observer must remain in a dark room from two to four minutes before attempting to use either of these instruments.

From Sir William Crooke's address, delivered recently before the International Congress for Applied Chemistry, in Berlin, we quote the following remarks. "The electrons produce phosphorescence of a sensitive screen of barium platinocyanide and the positive ions of radium produce phosphorescence of a screen of zinc blende.

If a few minute grains of radium salt fall on the zinc sulphide screen the surface is immediately dotted with brilliant specks of green light. In a dark room, under a microscope with a two-third-inch objective, each luminous spot shows a dull center surrounded by a diffused luminous halo. Outside the halo the dark surface of the screen scintillates with sparks of light. No two flashes succeed on the same spot, but are scattered over the surface, coming and going instantaneously, no movement of translation being seen.

SPINTHARISCOPE.

If a solid piece of a radium salt is brought near the screen, and the surface examined with a pocket lens magnifying about 20 diameters, scintillating spots are sparsely scattered over the surface. Bringing the radium nearer the screen the scintillations become more numerous and brighter, until, when close together, the flashes follow so quickly that the surface looks like a turbulent luminous sea. When the scintillating points are few there is no visible residual phosphorescence, and the successive sparks appear "atoms of intensest light," like stars on a black sky. What to the naked eye seems like a uniform "milky way," under the lens becomes a multiple of stellar points, flashing over the whole surface.

"Polonium" basic nitrate, actinium and radio-active platinum produce a similar effect on the screen, but the scintillations are fewer. In a vacuum the scintillations are as bright as in air, and being due to inter-atomic motion they are not affected by extremes of low temperature; in liquid hydrogen they are brilliant as at the ordinary temperature.

A convenient way to show these scintillations is to fit the blende screen at the end of a brass tube with a speck of radium salt in front about a millimeter off, and to have a lens at the other end. I propose to call this little instrument the "spinthariscope," from the Greek word spintharis, a scintillation."

This is the form of instrument shown in the lower part of the illustrations.

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The Transactions of the Institute of Mining Engineers, containing the report of the Albany meeting, have just been issued.

## INDUSTRIAL NOTES

The Edison iron-nickel alkaline storage battery has now been placed on the market.

Westinghouse, Church, Kerr & Co. have received an order for additional boiler and economizer equipments for the Detroit plant of the Solvay Process Co.

The Allis-Chalmers Company, of Chicago, recently received an order for a smelting plant, costing $17,500, from the Consolidated Mining & Development Co., of Spokane, Wash.

We have received from the National Oil Burner & Equipment Co., of Saint Louis, Mo., a pamphlet on the Branch furnace burners and oil heaters, for the use of fuel oil in boilers and furnaces. Information is also given on the properties of crude oil and the calorific power of various fuels.

The Westinghouse Electric & Manufacturing Co., of Pittsburgh, Pa., has received an order from the De Beers Consolidated Diamond Mining Co., Ltd., for twelve electric locomotives which will be used in the mines of the company at Kimberly, South Africa. The generating plant also contains Westinghouse machines.

The American Syndicate, which is interested in Guanajuato Light & Power Co., Ltd., are erecting a hydro-electric plant, capable of developing 10,000 horse-power, on the Prio de Valle, for transmission over 45 miles to the El Oro mining district, one of the most important mineral regions in Mexico. The transmission voltage will be 60,000, and the initial equipment will have a capacity of 4000 horse-power.

## PERSONAL.

Mr. Frank Klepetko, of New York City, is on a professional trip to Parral, Mexico.

Mr. Calvin W. Rice has resigned as second vice-president of the Nernst Lamp Company, of Pittsburgh, Pa.

Mr. Hennen Jennings has returned from Johannesburg to London and has taken office as president of the Institution of Mining and Metallurgy.

Mr. A. A. Knudson, of New York City, presented at the recent Detroit Convention of the American Works Association a paper on "Some Recent Effects of Electrolytic Action Upon Underground Mains and Other Metals."

Mr. Frank J. Buck, of Denver, Col., is at persent at the works of the Las Vegas Copper Co., in Las Vegas, New Mexico. They are treating about 50 tons of 3 per cent. copper ore per day, at a cost of 2.3 cents per pound of copper produced. Mr. Buck expects to have the San Miguel Works completed in August, which will treat 200 tons per day.

## DIGEST OF U. S. PATENTS PRIOR TO JULY, 1902.

*Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.*

Electrolytic Production of Hypochlorites—*Concluded.*

684,182. October 8, 1901. Frank J. Briggs, Everett, Mass.

Bleaches paper pulp or fabric made from animal or vegetable fiber, either in the electrolytic cell or in a separate vessel. The cell comprises a tank lined with glazed brick, with its bottom covered with a layer of cement. A transverse, vertical diaphragm divides the tank, near one end. This diaphragm is a wooden or iron frame, having stretched upon it a piece of asbestos cloth, the side of which toward the larger compartment of the tank is covered with cement. The other side of the cloth is supported by a plate of perforated iron. The anode is located in the main compartment, near the diaphragm, and consists of a frame supporting vertical, platinum wires, the lower ends of which extend into the layer of cement at the bottom of the cell, being there connected to a copper wire. The cathode is a vertical plate of iron or copper. A revolving agitator is located in the anode compartment, which receives the pulp. Electrolyte, a solution of sodium chloride and sulphurous acid.

685,274. October 29, 1901. Max Haas, Aue, Germany.

A number of bi-polar electrodes, each held in an insulating frame, are arranged transversely in the electrolyzer. The electrolyzer has openings through its bottom between each pair of electrodes, and is placed in an outer storage vessel, with the electrolyte just covering its upper edge. The hydrogen produced by electrolysis causes the solution to rise between the electrodes, and it then overflows the edge of the electrolyzer, passes down outside and re-enters through the bottom openings. The temperature of the electrolyte may be regulated by a cooling tube in the outer vessel.

699,907. May 13, 1902. George J. Atkins, London, England.

Electrolyzes brine to produce a bleaching solution containing one part of sodium chlorate and oxychloride to three parts of sodium chloride. The cell is a trough-like vessel of wood lined with carbon, which serves as the anode. A horizontal, cylindrical cathode of wood covered with lead revolves in the trough. The brine flows through the trough from end to end. A scraper of rubber or felt bears on the cathode to remove hydrogen. Potential difference, four volts. Any evolution of chlorine or formation of hydrochloric acid indicates defective working. The bleaching solution may be used directly or evaporated to give salts. Chlorine may be obtained from these salts by adding sulphuric acid.

702,142. June 10, 1902. Frederick H. Long, Chicago, Ill.

Bleaches paper pulp by adding it to brine, or a magnesium chloride solution, of a density of 12° to 18° Baumé, in sufficient volume to render the charge of the consistency of thick cream. Preferably adds five to ten pounds of quick lime to each 4000 pounds of the brine. The charge is circulated through a closed cell, under pressure. The cell is a vertical, cylindrical vessel of metal lined with wood. A horizontal, downwardly-dished diaphragm, of perforated wood covered with paper and canvas, subdivides the lower part of the cell. The carbon anodes are arranged in a circular series above the diaphragm; the cathode is a shallow, copper pan beneath it. The charge enters through a central opening in the top of the cell, passes downward over a conical spreader and through notches in its periphery, thence beneath the anodes and out through a central opening in the diaphragm. It is returned to the top of the cell by an air or steam ejector. The cell has a pressure gauge, level indicator, thermometer and outlet for hydrogen. The cathode products, sodium hydroxide, hydrogen and coloring matters are withdrawn and carried upward through a long pipe, by which the hydrogen is separated.

Electrolytic Production of Chlorates.

480,492. August 9, 1892. Elisha B. Cutten, New York, N. Y.

Produces potassium chlorate by electrolyzing, with carbon electrodes, a solution of magnesium chloride having a strength of from 15 to 20 per cent., to which is added potassium chloride and slacked lime in amounts "determined by the chemical combining proportions." Agitates the solution. The magnesium chloride is said to be primarily decomposed, its chlorine combining with the lime to liberate oxygen, which oxidizes the potassium chloride to chlorate. The magnesia may be recovered from the cathode, if the cathode compartment is separated from the anode by a porous cup. The cathode is then preferably a carbon lining in the containing vessel.

480493 August 9, 1892. Elisha B. Cutten, New York, N. Y.

Produces potassium chlorate by electrolyzing a solution of magnesium chloride containing potassium chloride and magnesia. Reactions similar to preceding.

491,701 February 14, 1893. Elisha B. Cutten, New York, N. Y.

Produces potassium chlorate by electrolyzing a mixed solution of magnesium or calcium chloride and potassium chloride with a current alternating at intervals of from ½ to 5 minutes. Carbon vessel, serving as one electrode; the other electrode, also of carbon, supported within it. The magnesia produced at the cathode combines with chlorine, when the current reverses, liberating oxygen, which converts the potassium chloride into chlorate.

492,003. February 21, 1893. Henry Gall, Hermes (Oise), and Amaury de Villardy de Montlaur, Paris, France.

Electrolyzes chlorides of the alkali and alkaline earth metals in a cell having a diaphragm. The hydrogen escapes from the cathode compartment and the caustic is continuously transferred therefrom into the anode compartment. Anode, platinum alloyed with 10 per cent. iridium; cathode, nickel or iron. Current, 50 amp. per sq. decimeter, at 4.43 volts. A pipe coil in each cell compartment keeps the electrolyte at from 45° to 50° C. Potassium and barium chlorates, being more soluble in their chloride solutions than in water, crystallize out in the anode compartment as the solution weakens. Sodium and calcium chlorates are recovered by removing the solution from the anode compartment, evaporating and first crystallizing out the chlorid and then the chlorate.

493,023. March 7, 1893. William T. Gibbs and Stanislaus P. Franchot, Buckingham, Canada.

Depolarizes the hydrogen by using a cathode of copper oxide plastered onto wire netting. The reduced copper is re-oxidized by removing the cathode, washing, drying and heating to a dull red in a current of air. The amount of copper oxide on the cathode should be such that it is entirely reduced when one-half potassium chloride in solution has been converted into chlorate. The heat necessary for producing the chlorate is generated by the oxidation of the hydrogen. The solution is withdrawn and cooled, the potassium crystallizing out. The residual solution is strengthened and returned to the cell.

519,400. May 8, 1894. Henry Blumenberg, Jr., Mount Vernon, N. Y.

Produces bromates and chlorates of the alkali and alkaline earth metals. Cell divided by a diaphragm. Anode, platinum; cathode, cobalt, platinum, iron, carbon or nickel. A pipe leads from the top of the anode compartment, which is closed, to the bottom of the cathode compartment, thus carrying the chlorine into the caustic. The cathode is agitated to facilitate the escaping hydrogen. A pipe withdraws the chlorate solution to a crystallizing vessel, from which the residual chloride solution is withdrawn, to be re-saturated and returned. Electrolyte maintained at 120° F.

536,848. April 2, 1895. Henry Blumenburg, Jr., Mount Vernon, N. Y.

Same as preceding patent.

537,179. April 9, 1895. Henry Blumenberg, Jr., Mount Vernon, N. Y.

Diaphragm cell. One pipe leads from the closed anode compartment to a gasometer, and another to a combining vessel. A pipe leads from the cathode compartment to the combining vessel. The chlorine and oxygen liberated at the anode are temporarily stored in the gasometer. The chlorine water from the anode compartment and the caustic solution from the cathode compartment are discharged into the combining vessel and the stored gases are then forced into the mixture. Steam coils in the cell maintain the temperature at 120° F. The cathode compartment may be closed and the hydrogen recovered. May electrolyze potassium chloride containing sodium chloride. The potassium and sodium chlorates are successively crystallized out. If the potassium chloride is impure, containing nitrates, the anode solution may be used for disinfecting.

565,324. August 4, 1896. Henry Blumenberg, Jr., Wakefield, N. Y.

Cell, a long trough containing alternate, rectangular, porous anode cups and cathodes. The anodes are of retort carbon, saturated with chlorine-substitution products of paraffin, ozocerite or asphaltum, and then coked; the cathodes are rectangular vessels of wire gauze, holding manganese peroxide which oxidizes the hydrogen and thus heats the electrolyte. The saturated brine flows successively through the several anode chambers and thence to a re-saturator. The caustic solution is run into a combining vessel, receiving chlorin from each anode compartment through a separate pipe. The residual chloride solution from the combining vessel is re-saturated and returned to the cathode compartment.

587,437. August 3, 1897. Ferdinand Hurter, Liverpool, Eng.

A series of superposed round or oval cells, separated by hard rubber rings. Each cell is a cast iron vessel, from the bottom of which a platinum sheet anode depends into the cell below. Each vessel has a porous lining, produced by applying successive coats of a mixture of two parts of Portland cement and one part of salt, with or without a little sand, until the lining is ¼ to ½ in. thick. The salt is then dissolved out. A potassium chloride solution rendered alkaline with caustic potash is introduced into the top cell and flows downward through several long glass or ebonite pipes, each connecting one pair of cells. Maintains the electrolyte at from 60° to 80° C.

587,696. August 10, 1897. Anthelme E. W. Boucher, Prilly, Switzerland.

Anode, a vertical plate of gold, platinum or carbon. Vertical connector bars of copper or iron are clamped against each side of the anode, being protected by insulation. The cathode is a rectangular, perforated sheath of brass or iron, surrounding the anode and spaced therefrom by rubber pieces. A hood to collect hydrogen extends outward from the electrodes, the whole constituting a portable unit.

627,000. June 13, 1899. Paul Imhoff, Liverpool, England.

Adds alumina or boron trioxid to solutions of alkali or alkaline earth chlorides. The alumina combines with the caustic to produce an aluminate, which does not divert the current like the caustic, yet reacts with the chlorine to produce hypochlorites or chlorates.

627,063. June 13, 1899. Paul Imhoff, Liverpool, England.

Prevents the reduction of hypochlorites and chlorates at the cathode by nascent hydrogen, by adding potassium chromate to the electrolyte, whether neutral or alkaline.

633,272. September 19, 1899. Thomas Parker, Tettenhall, Eng.

Covers electrolyte with a one-inch floating layer of pumice-stone or cork, in pieces the size of a hazelnut. This layer prevents the escaping gases from carrying off any of the electrolyte. Maintains solution at 30° to 40° C., by using a current density of 20 amp. per sq. ft. of cathode surface.

665,426 and 665,427. January 8, 1901. William T. Gibbs, Buckingham, Canada.

Cell consists of a series of rectangular frames of wood lined with lead. A lead plate faced on one side with platinum is clamped between each pair of frames. The cathode consists of a number of the thin vertical rods of copper or zinc, held away from the platinum anode, at a distance from 1/16 to ⅛ in., by horizontal insulating-rods. The cathode is electrically connected to the adjoining lead plate, which serves as the rear wall of each cell. The bubbles of hydrogen readily free themselves from the cathode rods. The solution is held at 110° to 120° F., by using a current of 3 amp. per sq. in. of electrode-surface. The temperature is regulated by controlling the inflow of the cold solution. The electrolyte may contain less than 3 per cent. of chloride. The chlorate solution is carried into a cooling and crystallizing chamber and the residual chloride solution is re-saturated and returned. The capacity of the cell is from 2 to 4 cu. ins. per sq. in. of electrode-surface.

703,861. July 1, 1902. A. A. Vogelsang, Dresden, Germany.

Brine flows alternately over and under bi-polar electrodes, each consisting of a plate built up of superposed square bars of slate cemented together and faced with thin platinum foil. The foil may be a zig-zag sheet, the portions extending between the bars serving as connectors for the electrode portions; or alternate bars may be sheathed with the foil. The electrodes are secured in vertical grooves in the side walls of the slate vessel by Portland cement. Current, 50 amp. per sq. decimeter.

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### NIAGARA MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The fourth general meeting of the American Electrochemical Society will be held at Niagara Falls on September 17 to 19, the preliminary programme being printed on another page of this issue. A good attendance is assured; for, next to New York City and Philadelphia, Niagara Falls has the largest local membership list, and—which counts probably more— the Niagara members represent a relatively large percentage of those who are building up by hard and steady work the electrochemical industries in this country. Such men are really the heart and soul of a technical society. Moreover, the charm of the Falls is ever fresh, so that the choice of Niagara for this meeting is fully justified, although the opinion which has found expression is not unwarranted that Niagara as a convention city appears to have been somewhat overdone in recent years. Some members may find it unnecessarily inconvenient and expensive to attend the convention of the American Institute of Electrical Engineers at Niagara in July, and the convention of the American Electrochemical Society again in September. In this era of commercial trusts, labor unions and union engineering buildings, a joint meeting of both societies would have been in order, and we regret that practical considerations prevented the realization this time in spite of the good will on both sides.

One special feature of the technical programme of the meeting appears to call for some comment, namely, a general discussion of the electrolytic dissociation theory to which one session is to be devoted. At its last convention the American Institute of Electrical Engineers gave a whole day to the discussion of engineering problems in connection with high-tension power transmission, which proved to be the most successful session of the meeting. We hope the discussion of the dissociation theory will be no less interesting or successful. The theory is now old enough to prevent such misunderstandings as were common when this hypothesis was first placed before the world in a somewhat pronounced and aggressive form. The dissociation theory has, without any doubt, inspired an enormous amount of excellent experimental work, and has thus done much good. Whether it is capable of change or improvement is, of course, another question, and should be a subject for a good discussion. While this subject is a specially attractive one for theorists to talk about, we would like to see practical electrochemical engineers join vigorously in the discussion at Niagara. It would be extremely interesting to hear from practical men what the dissociation theory has done for them, or where it has failed. After all, a theory is nothing but a tool, and its importance is to be estimated from its value as a "working hypothesis." Tools are capable of improvement, but to improve them it is necessary to understand clearly in which respect they are failing

## FACTS CONCERNING ELECTRIC STEEL PROCESSES.

For some time we have given considerable space to the discussion of electric steel processes. While we have gladly opened occasionally our columns to a discussion of future possibilities, yet we have mainly endeavored to disseminate knowledge of what actually has been done, by publishing correct and authoritative information on the work of the various inventors working in the field of electrometallurgy of iron and steel. This issue contains two interesting articles of this character. The one is a paper contributed to our columns by Dr. P. L. T. Héroult, who shares with Mr. Charles M. Hall the credit of having discovered the electrolyte now in universal use for the electrolytic production of aluminium, but whose activity in recent years has been mainly absorbed in improvements in the electrometallurgy of iron and steel. The other is a rather full abstract of a recent paper of Dr. Hans Goldschmidt of "thermite" fame, who gives a review of the present situation of the electrometallurgy of steel, and some especially interesting exact data concerning the product of the Kjellin process, operated at Gysinge in Sweden.

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The most important fact to which we call attention is the commercial success of the electric production of high-grade tool steels by Héroult and Kjellin. True, the beginnings are small, but both processes must be considered to be now beyond the experimental stage, since they are working continually and their products find a market. It was, of course, to be expected that electrical processes would achieve their first commercial success in the production of high-grade crucible steels, for the reason that the cost of their preparation by the old method is high, and the chief advantages of electrical methods—cleanliness, flexibility and perfect control—must appear here in the best light. For such purposes contaminations of the metal from the electrodes must be eliminated. Kjellin accomplished this in the most radical way—by using no electrodes at all. The metal forms the single-turn powerful current secondary of a transformer, and the electrical energy supplied to the primary winding appears in the secondary as heat. It would be interesting, however, to determine exactly the amount of magnetic leakage; this might not be inconsiderable in the construction chosen by Kjellin. Héroult uses what he calls "electrodes," but they do not dip into the molten metal and are no electrodes in the ordinary electrochemical sense, being only the terminals of the circuit from which arcs jump over to the molten metal. He obtains the heat mainly from radiation from his powerful arcs, and only to a comparatively small extent in the form of Joulean heat. It may be added that there are other methods available by which contaminations of the metal from carbon electrodes might be avoided.

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A brief remark in Dr. Héroult's article is especially worthy of attention, namely, that his process will soon be applied for the production of the best grade of tool steels in connection with a large blast furnace works where electricity will be produced by a blast furnace gas motor. This short note appears to indicate the lines along which commercial electrometallurgy of steel will probably develop. It is not probable that the electric furnace will soon supersede the blast furnace in general, but for special work, like the production of special high-grade kinds of steel, the electric furnace has proven to be a commercial success, and appears to have come to stay. It seems quite probable that in future electric furnaces will be operated side by side with blast furnaces, not in competition, but in co-operation with them. The splendid development of gas engines in recent years has made possible and practical the utilization of blast furnace gases—which are still wasted to a great extent—for the generation of electrical energy; and it would seem only a logical development to utilize this electrical energy for the operation of electric furnaces for special work to supplement the blast furnaces employed in the general ordinary work. While the industrial development of the electrometallurgy of aluminium has been intimately connected with water-power developments, it is quite probable that the future of the electrometallurgy of steel will to some extent be connected with the utilization of the waste gases from blast furnaces.

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## BLEACHING POWDER AND BLEACHING LIQUORS.

In this issue we publish an interesting article by Dr. W. H. Walker on the various methods in commercial use abroad for producing hypochlorites, or, as they are commonly called, bleaching liquors. The subject is certainly a timely one, in view of the fact that among the larger paper, pulp and textile mills of this country, there is a pronounced tendency to install their own electrolytic plants to produce the bleaching reagents used in their works. In all plants so far installed—the majority of which are in the New England States—diaphragm processes are used for making bleaching powder. This is in distinct contrast with the situation abroad, where a variety of apparatus, as described in Dr. Walker's articles, are in commercial use for the direct production of bleaching liquors.

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When Hermite first introduced hypochlorite apparatus into practice in a somewhat undeveloped form, his apparatus was experimented with in several mills of this country, but soon abandoned for the reasons mentioned by Dr. Walker. The only remains in this country of this type of apparatus appears to be a small and rather crude municipal plant in Philadelphia, under control of the Board of Health, the hypochlorite being used for disinfecting purposes. When we visited this plant last year, it was not in operation, for the reason that no funds were available, but it was expected that the plant would again be put in operation later.

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The contrast between the situation in this country, and the extended use of hypochlorite apparatus abroad was pointed out by Dr. F. Haber in his report on the electrochemical industry in the United States, which is, and will remain for quite a while, a fertile source for comment and discussion. Dr. Haber points out the reason why our paper and pulp mills prefer to use diaphragm cells, and to make their own bleaching powder. It is simply a matter of cost, since it is considerably cheaper to produce bleaching powder by the diaphragm process than to make strong hypochlorite solutions. What is wanted in pulp mills is usually a solution containing 25 grams of bleaching chlorine per liter; to produce such a strong solution a comparatively great amount of energy is required, for the reason that the ampere-hour efficiency of hypochlorite apparatus is rather low. It is therefore rather improbable that

pulp and paper mills will install hypochlorite apparatus, especially as the diaphragm cells now in use in this country are relatively cheap and efficient apparatus.

The situation is, however, quite different in the case of textile mills, laundries and bleacheries, since weaker solutions and smaller amounts of the same are here required. The great simplicity of operation of hypochlorite apparatus is also a point of importance. Moreover, as Dr. Walker remarks, the color of the finished goods is purer and more even if bleaching liquors are used; the solution penetrates the fibres more easily, giving a color of greater permanence; and there is no danger of the deposition of insoluble calcium salts producing a harsh or rough feeling on the goods. The fact—which we know to be a fact—is therefore not surprising that textile manufacturers of this country are beginning to consider the application of hypochlorite apparatus.

## ELECTROLYTIC PRODUCTION OF WHITE LEAD.

Our Digest of Electrochemical Patents prior to July 1, 1902, deals in the current issue with the electrolytic production of white lead, than which no more intricate and elusive subject is offered for the consideration of the technical electrochemist. The patents, however, give no adequate idea of the difficulties which arise in practice. As a rule the methods of the specifications are extremely simple, and in all cases they are described as cyclical in character; that is to say, the methods require for their indefinite continuance only the supply of the lead, carbon dioxide and water eliminated in the pigment. The principle of nearly all is the electrolytic solution of an anode of lead, and its subsequent chemical separation as basic carbonate by reaction with the alkaline solution from the cathode, supplemented by the action of carbon dioxide introduced into the cell or into a carbonating chamber, which receives the precipitated hydroxide.

The alkali metal nitrates, and acetates are the electrolytes commonly noted. Of these the former requires less c. m. f, owing to its depolarizing effect at the cathode, but its gradual reduction to nitrate and ammonia introduces changes in the composition of the bath, which are by no means negligible, and which correspond to a gradual deterioration in the character of the pigment. The basic carbonate must not only have the proper chemical composition, but it must comply with high commercial requirements as regards its color, its covering power, and its tinctorial effect. In these respects it is sensitive to minute changes of conditions, and the familiar problem of maintaining initially good conditions is here presented in its most serious aspect.

## ELECTROLYSIS AT SMOOTH AND PLATINIZED PLATINUM ANODES.

In this issue we publish a highly interesting article by Prof. F. Foerster, in which this distinguished German electrochemist sums up the results of the extended researches made by him and under his direction on electrolysis at smooth and platinized platinum anodes. The familiar phenomenon of "overvoltage" appears here in a new and interesting light. In the present case we have to deal with the development of oxygen at an anode which requires an overvoltage, and the anodic potential required for the generation of oxygen undergoes very peculiar changes during the course of electrolysis. Dr. Foerster shows that there is undoubtedly a change going on in the anode itself, but frankly admits that we do not yet know the exact causes which are at the bottom of the phenomena. Nevertheless, we now know the phenomena as they are, and Dr. Foerster is right in pointing out that our increased knowledge of the facts should help us in improving technical methods. In this connection the researches on the electrolysis of sodium chloride are especially interesting. Even if platinized platinum anodes should not be introduced into practice it is always important to know the ideal conditions for a process, even if they cannot be realized in practice. The technical man then has a goal to strive at, and can try to approach the ideal conditions as much as possible by different and through imperfect, yet practical, means.

## RARE METALS.

The recent development of special steels, that is, steels containing unusual and costly elements and possessing particularly valuable properties for particular purposes, is mostly responsible for a revival of interest in many of the rare metals. The result has been a ransacking of all known occurrences of these metals in nature, a general overhauling of the laboratory methods, for their qualitative detection and quantitative estimation, and a diligent search for new and improved methods of industrially extracting the pure metals or their pure compounds.

The discovery of comparatively large deposits of tungsten, molybdenum, vanadium and uranium ores in Arizona, Colorado and Canada, has in recent years made America the chief purveyor of these ores for commercial purposes. Our uranium and vanadium ores are particularly in demand, and regular shipments of these valuable materials are made from Colorado, via New York, to Europe. Unfortunately, we must here confess, that we are, to some extent, buying back these metals, or their alloys, from our European friends, after they have exerted their skill in extracting them from the ores we ourselves furnish.

To ameliorate this condition of affairs, not at all flattering to our American chemists and metallurgists, Mr. A. B. Frenzel, of Denver, offered last April a prize of two hundred and fifty dollars, to be awarded by the Governing Board of the American Electrochemical Society to the person submitting the best paper on "practical methods of treating the rare minerals found in America and extracting the rare metals therefrom"; the donor of the prize further agreeing to furnish free of charge any reasonable quantity of raw material at his disposal, viz., ores of uranium, vanadium, molybdenum and tungsten. We have reason to know that this offer has already greatly stimulated the study of these rare metals, and that many investigators in different parts of America, convinced of the need of careful work in this direction, are now devoting their energies to the problem. Almost coincidently with the occurrences mentioned above, we can record the publication of two American books treating exclusively of the subject in hand. They are analyzed in our columns for Book Reviews in this issue.

## NIAGARA FALLS MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The fourth general meeting of the American Electrochemical Society will be held at Niagara Falls, N. Y., September 17, 18 and 19, 1903.

The meeting will be held at the Auditorium of the Cataract House, beginning at 9 A. M., Thursday, September 17. Thursday and Friday afternoons will be devoted to visits to power houses and certain of the electrochemical plants which are open to visitors, and to other points of interest in the vicinity. Thursday evening there will be a smoker and entertainment at the Cataract-International, Friday evening a dance and reception at the Cataract House. Saturday evening will be devoted to a trip to Niagara-on-the-Lake, Youngstown and Port Niagara by boat and trolley.

The headquarters will be at the Cataract House. The special rates at the Cataract House and International Hotel are $3.50 to $5.00 per day, American plan. For further information concerning hotels, address the local secretary, Mr. C. L. Collins, 2d, Niagara Falls, N. Y.

The following titles ot papers have been announced:

"A New Type of Electrolytic Cell."—P. G. Salom.

"Manufacture of Ferro-Alloys in the Electric Furnace."—Dr. George P. Scholl.

"Electrolytic Copper Refining."—Dr. W. D. Bancroft.

"Electrometallurgy of Gold."—Dr. W. H. Walker.

"Some Theoretical Considerations of Resistance Furnaces."—F. A. J. FitzGerald.

"On the Supposed Electrolysis of Water Vapor."—F. Austin Lidbury.

"Efficiency of the Nickel Plating Tank."—Prof. O. W. Brown.

"Electrolysis of Sodium Hydroxide, by Alternating Current."—Carl Hambuechen.

"A Practical Utilization of the Passive State of Iron."—Prof. C. F. Burgess.

"Theoretical Properties of Free Ions in Solutions."—Dr. E. F. Roeber.

"Berthelot's Law of Electrochemical Action."—C. J. Reed.

Other papers are expected from Dr. J. W. Richards, David H. Browne, Dr. L. Kahlenberg, Prof. C. F. Burgess, A. H. Cowles, and others.

One session of the meeting will be devoted to the discussion of the theory of Electrolytic dissociation, which will be opened by Dr. W. D. Bancroft.

Volume III. of the Transactions of the Society has recently been mailed to the members. On not less than 445 pages a complete report of the proceedings of the third general meeting, held at New York City from April 16 to 18, is given. Besides Dr. Richards' presidential address on Conditions of Progress in Electrochemistry, the volume contains twenty-eight papers, together with a report of the discussion which followed each paper.

As an appendix, Mr. William J. Hammer's lecture on "radium and other radioactive substances with a consideration of phosphorescent and fluorescent substances; the properties and applications of selenium and the treatment of disease by ultra-violet light" is represented.

Presswork and illustrations are highly creditable.

## TUNGSTEN, MOLYBDENUM, URANIUM AND VANADIUM IN 1902.

In view of the increased importance of rare minerals in recent years—which led Mr. A. B. Frenzel, of Denver, Col., to offer a price to the American Electrochemical Society for the best investigation on this subject—the following abstract of a report of Dr. Joseph Hyde Pratt to the United States Geological Survey will prove of interest.

The production of crude tungsten ores during 1902 amounted to 183.5 tons, of which not more than a few tons were sold. The production of 1901 was 179 tons of concentrated ore, valued at $27,720. The larger part of the production of 1902 was from Colorado, with a smaller amount from Connecticut. No new localities were developed during 1902.

Almost the entire production of commercial molybdenite was by the Crown Point Mining Company, of Seattle, Washington, from their property in the western part of Chelan County. The production amounted to about 12 tons. The value of the ores is very erratic, the prices quoted varying from $1,500 to $100 per ton.

There was a marked increase in the production of uranium and vanadium minerals in 1902, which, as reported to the survey, amounted to 3810 tons, valued at $48,125, or $12.63 per ton. This, of course, represents the crude ore. In 1901 the production was 375 tons of crude ore. A portion of the uranium ore was treated, giving a concentrated product of 25 tons, which was valued at $8,000, or $320 per ton.

Although it has been determined that these metals have beneficial effects when used in the manufacture of steel, considerable study of them is necessary before their commercial position with respect to one another or to nickel and chromium can be definitely determined. Questions came up as to which of the various irons hardened by them are best adapted for steel drills, for dies and shoes in stamp mills, for car axles, carpenters' tools, etc., as to which will retain the best cutting edge, which will heat the least when in use, and which will make the toughest iron.

## PRODUCTION OF BARYTES IN 1902.

The production of crude barytes in 1902, as reported to the United States Geological Survey by Dr. J. H. Pratt, was considerably in excess of that of 1901, amounting to 61,548 short tons, valued at $195,983, as compared with 49,070 tons, valued at $157,844, in 1901, an increase of 12,478 tons in quantity and of $38,139 in value.

The States producing barytes in 1902 were Virginia, North Carolina, Tennessee, and Missouri. Both Virginia and Missouri largely increased their production; in Tennessee there was a large falling off in production.

Whereas barytes was formerly considered as an adulterant in the manufacture of paints, it is now beginning to be recognized that barytes has excellent qualities of its own that make it of value as a pigment. When it is used in combination with white lead or with zinc white these qualities appear to advantage, since its pure white color is permanent and is unaffected by the weather or by gases that in some cases blacken white lead.

## PRODUCTION OF CHROMITE IN 1902.

The report to the United States Geological Survey on chromite for 1902, by Dr. Joseph Hyde Pratt, is now in press.

California was the only State producing any chromite during 1902, the quantity being 315 long tons, valued at $4725. This is a decrease of 53 tons in quantity and of $1065 in value, as compared with the production in 1901, which was 368 long tons, valued at $5,790.

The Pacific Coast offers a promising field for the erection of a chemical plant to treat chrome ores for the manufacture of various chromium salts, as these ores can be obtained in California.

With the completion of the railroad from Erwin, Tenn., to Marion, N. C., the chromite deposits of Yancey County, N. C., will undoubtedly be thoroughly exploited and may become producers.

There is a large amount of chromite ore imported each year into this country, the most of which is from Turkey, with smaller amounts from New Caledonia and Canada. The imports of chrome ore and chromic acid in 1902 were valued at $503,712. The principal chromite deposits of Canada are in the vicinity of Black Lake and Colraine, Quebec Province. The Canadian production for 1902 was 000 long tons, valued at $13,000.

## ELECTROLYTIC PRODUCTION OF BLEACHING LIQUOR.

By W. H. WALKER, PH. D.

As long ago as the year 1774 the Swedish chemist Scheele discovered the element chlorine and noticed that it possessed the property of decolorizing organic material. Chlorine in this form soon found application in the arts, especially in the bleaching of paper stock, but as the action was very difficult to regulate much loss was experienced in its use. It was therefore a great step in advance when eleven years later Berthollet found that if a potash solution were used to absorb the chlorine, instead of water, a very superior bleaching solution was obtained. The work was done at Javelle, near Paris, and this solution soon became known as Eau de Javelle. When later the cheaper soda was substituted for potash the solution received the name of Eau de Laborraque. These bleaching solutions were, however, very unstable, and it was not until Tennant of England discovered that dry calcium hydrate could be used to absorb chlorine gas, and that in this form chlorine available for bleaching could be stored and transported that the use of Berthollet's discovery was made generally available.

Contemporary with these developments came the introduction of the Leblanc soda process, with its great production of hydrochloric acid. In order to utilize this by-product the makers of soda became manufacturers of bleaching powder, and this material soon displaced the older directly prepared bleaching liquors.

As early as 1800 Cruikshank had observed that when an electric current was passed through a solution of common salt chlorine was set free at one electrode, and caustic soda was formed at the other. Twenty years later Brandé proposed the utilization of this reaction by allowing these two substances to unite as did Berthollet, and suggested the use of electrolyzed sea water as a bleaching solution. A number of years after this Lardenois prepared a bleaching liquid which he called "electro-chlorigen" by the electrolysis of brine, using a platinum plate as an anode, and a lead plate as a cathode. From this time on a great number of investigators studied this subject, but owing largely to the great cost of electrical energy and ignorance of the secondary reactions which take place in the electrolysis of brine, they all failed in establishing the art upon a practical commercial basis.

Although the reaction which takes place when chlorine is absorbed in caustic soda was early shown to be $2\,NaOH + Cl_2 = NaCl + NaOCl + H_2O$, it was not until very recent years that several factors which obtain during the electrolysis of brine, and which have a marked influence on the result, were fully studied or appreciated. While the systems for producing bleaching liquor electrolytically, to be mentioned later, differ widely in detail, the principles involved are practically identical in each, so that the theory of their action may be studied independently of the apparatus.

The formation of sodium hypochlorite by the action of the chlorine set free at the anode of an electrolytic cell upon the caustic soda formed at the cathode is in itself a quantitative one. In practice, however, the increase of hypochlorite as measured by the amount of electricity sent through the apparatus is found to be a constantly decreasing quantity as the operation is continued. The principal factors active in bring-

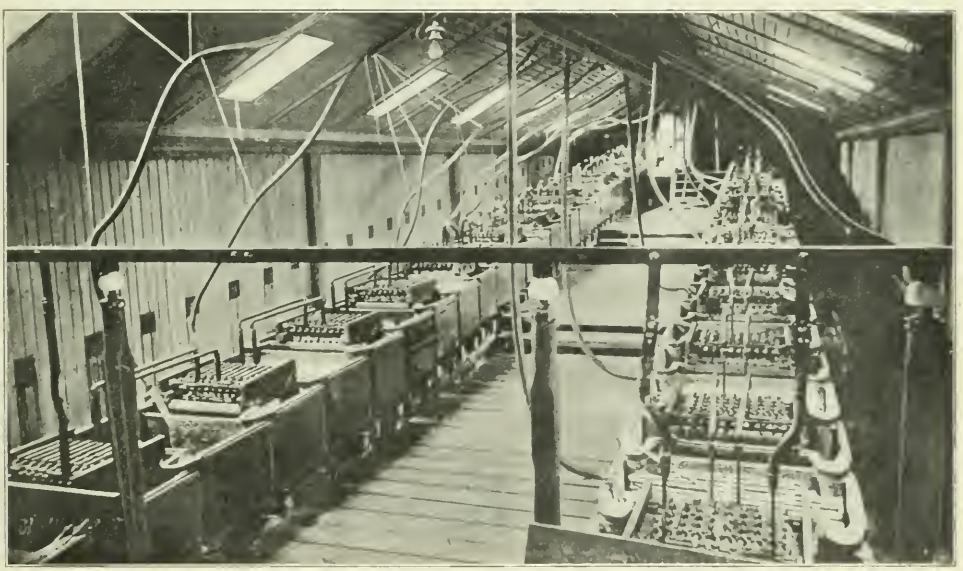


FIG. 1. INSTALLATION OF SCHUCKERT APPARATUS.

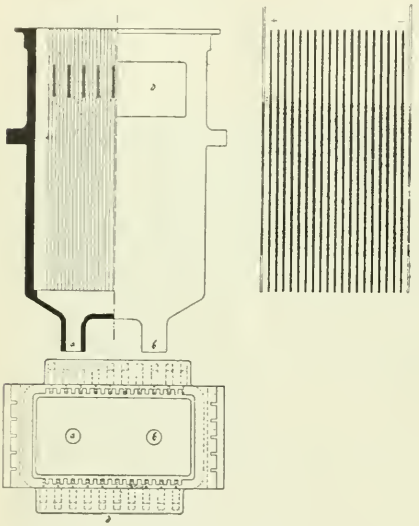
ing about this decreasing current efficiency, which must be recognized in the design of an efficient apparatus for the production of hypochlorite, are the following:

1. So soon as sodium hypochlorite is formed in the electrolyte it commences to take a part in transporting the electric current and the $ClO$ ions move toward the anode. As the $ClO$ ions are discharged at a lower potential than $Cl$ ions, all the former, when they reach the anode, receive a positive charge, and, reacting with water, form hypochlorous acid with the liberation of oxygen. This action, with its consequent loss of electrical energy, must become ever greater as the concentration of the electrolyte in hypochlorite increases. That the liberation of oxygen may be reduced to a minimum the anode should be as small as possible compared to the bulk of the electrolyte in order to decrease the opportunity for the $ClO$ ions to come in contact with the electrode. With an increasing current density, however, the resistance rapidly rises so that the small an electrode means excessive loss in power.

2. Although sodium hypochlorite is relatively stable at ordinary temperatures, it easily breaks up when heated to 50° or 60° C., largely according to the equation $3\,NaClO = NaClO_3$

$+2\ NaCl$. The chlorate thus formed is of no value as a bleaching agent, and the reaction should therefore be prevented by maintaining the temperature of the electrolyte at a low figure. As heat is being constantly generated, both by the passage of the current through the bath, and by the formation of hypochlorite, it is found advisable to provide a cooling system in some part of the apparatus. Since the water used for the purpose is in no way contaminated by its passage through the system, no operating expense is in this way introduced.

3. Hydrogen in its molecular or gaseous state has no reducing action upon hypochlorites; at the moment of its formation on the cathode, however, it rapidly decomposes these com-



FIGS. 2, 3, 4.—SIEMENS & HALSKE APPARATUS.

pounds with the formation of water, and the corresponding chlorides. It will be seen, therefore, that the sodium hypochlorite in the electrolyte will be destroyed in coming in contact with the cathode in proportion as its amount increases. This difficulty may be in part overcome by employing small cathodes; but, as in the case of the anodes, this reduction in size is limited by the consequent increase in the resistance of the cell. Another method of overcoming the reducing action of the nascent hydrogen is by adding to the electrolyte a substance which will be continuously deposited in the form of a film upon the cathode, and in this way envelop the hydrogen as set free, until it forms bubbles of molecular gas and passes out of the solution. The hydrates of calcium and magnesium act to a certain extent in this way; later developments along this are the patents of Imhoff for the use of chromates and aluminates, and of Schuckert & Co. for the addition of sodium resinate to the brine to be electrolyzed.

The strength of salt solution which is most economical to electrolyze, depends upon the amount of available or active chlorine, which it is desirable a litre of the resultant bleaching solution should contain, and on the relative local cost of salt and electrical energy. In general it may be said that raising the concentration of the salt solution lowers the resistance of the bath, increases the current efficiency, and thus for a given yield of chlorine decreases the consumption of energy; it increases, however, the consumption of salt. Complete mixing of the products set free at each electrode is, of course, necessary to prevent the escape of the chlorine before it has had opportunity to react with the caustic soda; in other words the electrolyte must circulate freely within the apparatus.

Every few hours the direction of the curent should be reversed in order that the accumulated insoluble hydrate on the cathodes may be dissolved away; otherwise the resistance is abnormally increased.

The first system for producing bleaching liquor on a commercial scale to be even moderately successful was that of Hermite, introduced in 1884. His apparatus in its final form consisted in a rectangular box of galvanized iron around the top of which ran a trough or channel to carry away the overflow of liquor fed in through a perforated pipe at the bottom. Two shafts ran through the box, carrying numerous discs of zinc, which dipped into the liquor and together with the box formed the cathode of the system. In the space between each pair of discs was a lead form supporting a platinum gauze; these were connected together and formed the anodes. At first it was thought necessary to electrolyze a solution of magnesium chloride, but later it was found that equally good results could be obtained by using common salt, which carried a small quantity of this compound. This process was given extensive trial in America at the soda pulp mill of the Forest Paper Co., of Maine, and at Cumberland Mills, Maine, at the plant of S. D. Warren & Co. Great difficulty was experienced in maintaining the relatively high content of available chlorine necessary to bleach cellulose derived from wood, so, after a year or so both plants were dismantled. We understand, however, that in Norway and Sweden there are in operation several mills which are using this process very successfully.

The only other system which has had extensive trial in America is that of Woolfe, designed to furnish liquor to be used for both bleaching and disinfecting purposes. This process is little more than a crude and comparatively inefficient form of the Hermite process, and after being for some time in operation at the plant of the Duncan Paper Co., Mechanicsville, N. Y., and one or two mills in Pennsylvania, it was finally abandoned.

In Europe, however, greater success has met the attempts to compete with bleaching liquor made from dry chloride of lime. Soon after the work of Hermite, Carl Kellner, a pioneer in the electrolysis of brine, patented a number of processes and types of apparatus for making sodium hypochlorite. The form which Kellner's ideas have finally taken, and which has

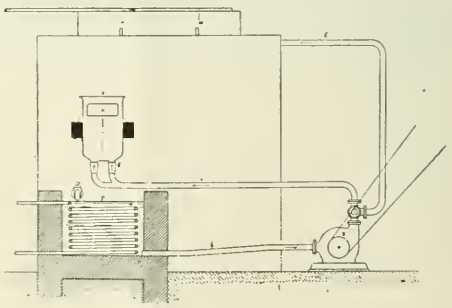


FIG. 5.—SIEMENS & HALSKE APPARATUS.

been perfected and put upon the market by Siemens & Halske, of Vienna, is as follows. A glazed stoneware vessel seen in two sections in Figs. 2 and 3 is divided into a number of small compartments by glass plates fitting into small grooves in its side. These plates are wound with platinum iridium wire, as shown in Fig. 4, and form bipolar electrodes from which the current passes in series through the solution in each compartment. There are holes in the bottom of the vessel through which the brine enters and overflow spouts at the top from

which the electrolyzed solution flows. Directly under the electrolyzing apparatus is placed a tank provided with a cooling coil of lead pipe, as shown in Fig. 5. The cooled solution is continually raised from the tank to the electrolyzer by the hard lead centrifugal pump, and after passing the electrodes falls again to the cooling tank. This circulation is continued until the content of available chlorine has reached the desired figure, when, by turning a three-way cock the finished bleach solution is forced to the storage reservoir above. Siemens & Halske own the Imhoff patents already referred to, and have recently

FIG. 6.—HAAS AND OETTEL APPARATUS.

made improvements in the apparatus as figured above, which is said to effect a marked economy in operation.

The standard types of apparatus and (when working a nine-tenths per cent. brine) guaranteed production are given as follows:

| Type | Volt | Amps. | Kilo-watts | Kgs Cl per hour | Kgs Cl in 22 hours |
|---|---|---|---|---|---|
| E K 110-120 | 110 | 120 | 13.2 | 1.50 | 33 |
| E K 110-60 | 110 | 60 | 6.6 | 0.75 | 16.5 |
| E K 110-30 | 110 | 30 | 3.3 | 0.40 | 8.8 |
| E K 110-15 | 110 | 15 | 1.6 | 0.20 | 4.4 |
| E K 60-120 | 60 | 120 | 7.2 | 0.80 | 17.6 |
| E K 60-60 | 60 | 60 | 3.6 | 0.40 | 8.8 |

This system is in use in a considerable number of bleacheries, laundries and pulp and paper mills in Europe, a large installation being at the works of the Kellner-Partington Paper Co. in Austria.

Another method for producing bleaching liquor, much used on the Continent, is that known as the Schuckert system. The latest form of this apparatus is manufactured by the Siemens-Halske Co., of Berlin, and is shown in Fig. 8. The electrolyzers are large troughs of stoneware or other resistant material separated into eight or ten compartments. In these compartments are bipolar electrodes of peculiar construction, in which platinum-iridium wire may or may not be used. The brine enters one end and traverses the cell in a zigzag fashion, being constantly mixed by the escaping hydrogen gas. No pump or other external means of insuring circulation is employed. Each cell is provided with a cooling coil through which a stream of water is maintained. The units are built in pairs and are designed to be used on a 110-volt circuit. The standard types of apparatus with the output of each, is given as:

| Type | Kg active chlorine in 10 hours | Liters of bleaching solution | Amperes at 110 volts |
|---|---|---|---|
| P 35 | 4.45 | 225 | 35 |
| P 50 | 6-6.5 | 340 | 50 |
| P 75 | 10 | 500 | 75 |
| P100 | 13 | 650 | 100 |
| P125 | 16 | 800 | 125 |
| P150 | 20 | 1000 | 150 |

The relation between concentration of active chlorine and the energy and salt consumed is shown by the following data:

A 10 per cent salt solution in traversing a pair of electrolyzers may have according to its speed a final content of chlorine.

| Grams per liter | Energy consumed in kw per 1 kg chlorine | Salt used in kilos per 1 kg chlorine |
|---|---|---|
| 20-22 | 7 | 5- 5.3 |
| 16 | 6 | 6- 6.5 |
| 10-12 | 5 | 10-10.6 |

By using a 15 per cent brine the energy is reduced and the salt consumption increased as follow:

| Grams Cl per liter | Energy in kw | Salt in kilos |
|---|---|---|
| 20-22 | 5.5-6 | 7.5- 8 |
| 10-12 | 4.5-5 | 15-16 |

With a 20 per cent salt solution a concentration of 45 grams per liter may be obtained, although in this case the current efficiency falls to 45 per cent. It has in general been found advisable to produce a solution containing 20 grams of active chlorine per liter and to later dilute with water to the desired strength. In the accompanying Fig. 1 is seen a plant located at Billingsfors, Sweden, which supplies the liquor necessary to bleach 16 tons of soda spruce cellulose per day. By the Siemens-Schuckert Co. is controlled the patent already referred to for the use of sodium resinate ("resin soap") in reducing the destructive action of hydrogen on the hypochlorite. The thin film of colophonium doubtless acts as a continuously forming and evidently an efficient diaphragm.

The third system which has become prominent in Europe is that of Haas and Oettel. The electrolyzers are built and sold by Haas and Stahl, Aue in Saxony. The earlier forms were intended for bleacheries and laundries, and an apparatus complete with the necessary reservoir for brine and storage tank for finished bleaching liquor is shown in Fig. 6.

The electrolyzer proper consists in a small rectangular box of a resistant tar or asphalt composition, divided into small

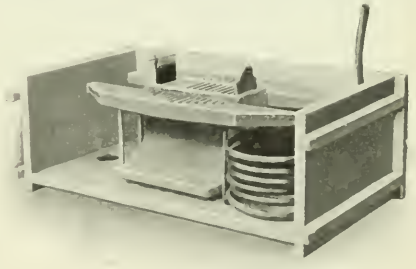


FIG. 7.—LATEST FORM OF HAAS AND OETTEL APPARATUS.

compartments by a series of vertical bipolar carbon electrides, set in insulated grooves. A 4B salt solution passes through oblique perforations in the electrode, which are out of alignment, and receives more or less of a whirling motion, which aids in its thorough mixing. It issues from the lower end of the electrolyzer as liquor containing about 3 grams of active chlorine per liter.

A later modification capable of yielding liquor carrying 20

grams of available chlorine per liter is shown in Fig. 7. The electrolyzer itself is placed in a large wooden box, which is to hold the salt solution to be decomposed. At the bottom of each small compartment are two holes, opening to either side of the electrolyzer at its lower edge. The top of each compartment overflows into a canal which empties at one end of a side piece running the length of the box. When the current is turned on hydrogen is set free in each compartment and mixing with the brine raises the specific gravity of the mass to such an extent that the liquor within the cells fails to balance that on the outside. As a result a current is set up in the liquor, the brine in the tank passing into the apparatus through the holes at the bottom and overflowing through the canals which empty at the corners of the box. A cooling coil is provided by which the temperature is kept below 24° C.

On account of the absence of platinum this type of apparatus is comparatively cheap. Each unit is designed to take about 75 amperes from an ordinary lighting circuit. In a salt solution of from 4 to 6B° one kilo of active chlorine may be produced by the expenditure of energy equivalent to about 6½ hp-hours.

It was the pleasure of the writer to see two of the above units in operation at the cotton mills of Wolle & Co., at Aue. Each electrolyzer sat in a wooden tank holding 1000 liters of 12 per cent brine. The circulation of the liquor through the tank and electrolyzer seemed to be all that could be desired, the operation progressing without attention and without any appreciable odor of chlorine. The content of active chlorine in the liquor is brought up to 15 grams per liter in the electrolyzers, and when ready for use is diluted to about 3 grams per liter. The cotton cloth is drawn through the solution, pressed lightly between rolls and allowed to stand for three or four hours in the air. A high color is in this way produced and the goods are then soured in a very dilute acid and washed. The specially prepared carbons in use were said to have been in active service for one and one-third years, the plant bleaching from 15,000 to 20,000 pounds of cotton daily; they showed however, little sign of disintegration or wear. A large number of plants have been equipped with the apparatus, one of 120 hp being for the North German Lloyd Steamship Co., at Bremen. Here all the linen from the company's many ships is washed and bleached. Although the principle on which the bleaching action of all hypochlorites depends is the same, experience has shown that for equal concentration of active chlorine, as shown by analysis, that held as sodium hypochlorite produced electrolytically, is much the more powerful in its action. This difference in the bleaching power varies with the material acted upon, but on the average lies between the ratios 3:2 and 5:4. This is doubtless due to a more efficient use of the available chlorine brought about in part by the absence of free alkali in its solution, which renders possible the presence of a greater amount of free hypochlorous acid and also in part by the greater solubility and rate of diffusion of the sodium salts as compared with calcium salts.

Unquestionably there are in the use of electrolytically prepared bleaching liquors advantages not possessed by those made from chloride of lime. The color of the finished goods is purer and more even; the solution penetrates the fibres more easily, giving a color of greater permanence; there is no danger of the deposition of insoluble calcium salts producing a harsh or rough feel on the goods. The cost of plant, especially where carbon electrodes are used, is not great when compared with our diaphragm cells, and the labor of repair and operation is much less. For laundries, bleacheries and textile works generally processes of the kind above-mentioned deserve more attention from Americans than they have as yet received. For our large pulp and paper mills, especially those in which caustic soda is used to reduce the wood to fibre, the diaphragm cells seem to have the advantage. For, leaving out of consideration the somewhat increased consumption of power and salt, the fact remains that in the systems for the direct production of bleaching liquor we are using the relatively expensive caustic soda, when the cheap caustic lime may be employed.

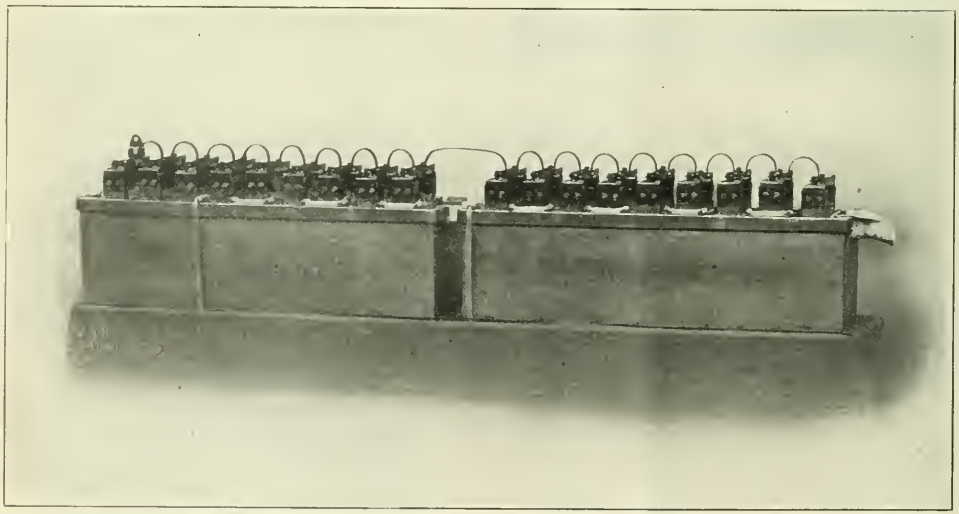


FIG. 8.—SCHUCKERT APPARATUS.

## JOURNAL DE CHIMIE PHYSIQUE.

While Germany has Ostwald's *Zeitschrift f. Physikalische Chemie*, and the United States Bancroft's *Journal of Physical Chemistry*, no journal specially devoted to physical chemistry was published up to the present in the French language. To fill this need, the *Journal de Chimie Physique* has just been founded. It is to appear as a monthly. Prof. Phil. H. Guye, of Geneva, Switzerland, is editor. We wish every success to our new contemporary.

# ELECTROLYSIS AT SMOOTH AND PLATINIZED PLATINUM ANODES.

BY PROF. F. FOERSTER, PH. D.

## DIFFERENCE IN THE BEHAVIOR OF SMOOTH AND PLATINIZED ANODES AT WHICH NO OXYGEN IS EVOLVED.

If an electric current of any strength shall enter an electrolyte through an inert anode, the latter must be at a potential which is sufficient in the electrolyte to enable that chemical reaction to take place which requires the least amount of chemical work at this electrode. This work is generally determined by the potential which the substance to be separated impresses in its turn on an electrode which dips into the same electrolyte.

To explain this statement by an example, we may discuss the electrolysis of a neutral normal solution of potassium iodide. The current will perform here at a platinum anode the separation of iodine, as this requires the least amount of work, and the iodine will soon saturate the solution in the immediate neighborhood of the anode. The potential, which the anode must have in order to enable this reaction to take place, is the same as that of a sheet of platinum in a normal solution of potassium iodide saturated with iodine. This is according to the formula of Nernst:

$$e = \frac{0.002\,T}{2} \log k \frac{C_{I_2}}{(C_I)^2}$$

in which T is the absolute temperature, $C_{I_2}$ the concentration of free iodine, $C_I$ the concentration of the iodine ions at the anode, and $k$ a constant. The value of $e$ in this case equals—0.56 volt against the normal hydrogen electrode.

If the electrolysis is carried out with a comparatively high anodic current density, more iodine ions will be discharged at the anode than can be brought back by diffusion to the anode in the same time. The concentration of the iodine ions will, therefore, become smaller near the anode than in the rest of the electrolyte, and the anode potential must increase. But with increasing difference of concentration between the neighborhood of the anode and the rest of the solution, the velocity of diffusion towards the anode increases, and, on account of the change in specific gravity, the impoverished solution is also carried away from the anode by convection; a condition will, therefore, soon be reached, when no further decrease of the number of iodine ions at the anode occurs, compared with the rest of the electrolyte, and, therefore, the anodic potential becomes constant. The value reached in this way, depends mainly on the current density.

It is thus clear that it is of importance whether the electrode, from which a certain current of a certain intensity, enters the electrolyte, is smooth or rough. In the latter case the surface of the electrode is increased, the current density, therefore, decreases, and, what may be of still greater importance, the electrode reaches with its higher points further into fluid-strata, in which, when the electrolyte near the deeper points of the electrode is strongly impoverished, a part of the electrolytic action may take place, until the impoverishment has been somewhat relieved.

A rough anode of considerable active surface is obtained by coating a sheet of platinum with platinum black. If the platinizing is done with a pure solution of hydrochloroplatinic acid, there is obtained in most cases a coating of gray platinum sponge, which has little effect. In order to be sure to obtain a deep black coating of platinum, according to Lummer and Kurlbaum[1] 0.025 gram of crystallized lead acetate is added to a solution of about 1 gram of platinum in 100 cc, and the sheets of platinum are platinized in this solution with a current density of 0.03 amp. per square centimeter for 1 to 2 minutes.

The influence of platinizing on the anode potential cannot be very considerable; this is shown by the above formula of Nernst. From this we see that, for instance, a diminution of $C_I$ to one-tenth of its value at ordinary temperature (17° C.) would raise the anode potential by 0.058 volt only. An impoverishment of the ions to be discharged to much less than say 1/100 of the initial value is, however, scarcely probable.

In agreement with this theoretical result is the observation[2] that in the electrolysis of an alkaline potassium iodide solution at a given constant current strength, the voltage is increased only by 0.07 volt, if the platinized anode is replaced by a smooth one. F. Salzer[3] made a similar observation when he electrolyzed an oxalic acid solution with a small current density; under these circumstances it is oxidized at the anode to carbonic acid with a current efficiency of 100 per cent.; the substitution of a smooth anode for the platinized one, every thing else being the same, caused an increase of potential by 0.12 to 0.21 volt only. The difference is greater here than in the case of the potassium iodide, because the smooth anode covers itself with large bubbles of carbonic acid, which adhere to it for quite a while and render the approach of the electrolyte to the electrode very difficult.

While in these observations which are in satisfactory agreement with the theory, the differences between the potential required for rough and for smooth anodes are small, considerably greater differences are observed, when hydrogen, and especially oxygen, are developed at the electrodes.

## THE POTENTIAL REQUIRED FOR THE BEGINNING OF THE ELECTROLYTIC GENERATION OF OXYGEN.

Poggendorff[4] found as far back as 1847 that for the electrolysis of a solution of sulphuric acid a considerably greater voltage is required between smooth platinum electrodes than between platinized ones. In the first case, as was established more accurately later on by Fromme,[5] there is required a voltage of 2.5 to 3.0 between the electrodes, while in the latter case only 1.8 to 1.9 volts are necessary under the same experimental conditions.

The question now arises whether the generation of hydrogen at the cathode, or that of oxygen at the anode, or both, cause this extraordinary increase of e. m. f. The facts show that the latter is the case. It is well known[1] that the first bubbles of hydrogen appear at a rough cathode always at a somewhat lower cathode potential, than at a smooth cathode of the same material. It has not yet been systematically investigated how large the increase of potential will be with a somewhat greater current strength. But it is known[7] that, for instance, the cathode potential required for the generation of hydrogen from sulphuric acid is greater by about 0.25 volt at a spongy lead plate than at a smooth lead plate.

The anodic potential, required for the anodic generation of oxygen, has been more thoroughly examined of late. The potential, which is impressed by oxygen of atmospheric pressure on a platinized electrode dipping into sulphuric acid of normal H concentration is about 1.13 volt against the normal hydrogen electrode,[8] and the same difference of potential is shown by a hydrogen oxygen gas cell in caustic alkali. If one impresses, however, on a small metallic electrode a potential different by 1.12 to 1.13 volts from that which hydrogen possesses against the same solution, then a small current begins to pass through the electrolyte and hydrogen appears at the cathode, but it does not come to a generation of oxygen gas at the anode; there is formed instead in the solution an oxydizing agent whose nature is still unknown and which is likely to be the source of the peroxide of hydrogen appearing at the cathode. For the generation of gaseous oxygen which is coincident with the passage of a stronger current, a considerable increase of the anode potential above 1.13 volt is necessary, and, as has been shown by the very interesting ex-

[1] See Kohlrausch, Wiedemann's Annalen, v. 60, p. 315.

[2] Forester and Mueller, Zeitsch. f. Electrochemie, v. 8, p. 534.
[3] Zeitsch. f. Electrochemie, v. 8, p. 898.
[4] Pogg. Ann., v. 70, p. 177.
[5] Wiedem. Ann., v. 28, p. 362.
[6] E. Mueller, Zeit. f. Anorgan. Chem., v. 26, p. 1.
[7] Strasser and Gahl, Zeitsch. f. Electroch., v. 7, p. 11.
[8] Bose, Zeitsch. f. Electrochemie, v. 7, 673.

periments of Coehn and Osaka,[9] this potential depends on the nature and the condition of the surface of the anode. It has been found that the following potentials must be impressed on an anode in caustic potash against a hydrogen electrode in the same solution, in order to enforce the passage of a strong current with generation of oxygen:

| | |
|---|---|
| At spongy nickel | 1.28 volts |
| At smooth nickel or cobalt | 1.35 " |
| At iron | 1.47 " |
| At platinized platinum | 1.47 " |
| At smooth platinum | 1.67 " |
| At gold | 1.75 " |

In future it will be very interesting to examine by experiment the conclusions which may be drawn from these facts, and which are theoretically and practically of equal importance.

The above values only relate to such very small currents as flow when the e. m. f. between the electrodes is just a little above the voltage of decomposition. Concerning other points of the behavior of anodes at which oxygen is generated, we have a more definite knowledge only in the case of the two kinds of platinum anodes. The investigations on this point, which I have carried out together with my colleague, Dr. Erich Mueller,[10] in the electrochemical laboratory of Dresden, and which were continued by other gentlemen experimenting there, have shown that there are other differences in the electrochemical behavior of both kinds of electrodes, besides the overvoltage (Ueberspannung) required for the generation of oxygen at smooth platinum over that required at platinized platinum, as indicated in the above table.

### ON THE POTENTIAL OF SMOOTH AND PLATINIZED PLATINUM ANODES AT WHICH OXYGEN IS GENERATED.

It is possible to obtain by the following simple means an idea of the changes which the potential of an anode at which oxygen is generated undergoes during the passage of the current.

If we electrolyze an electrolyte which gives oxygen at the anode—like sulphuric acid or caustic soda—with two vertical platinized platinum cathodes, while the platinum anode suspended between them is either smooth or platinized, we notice that the voltage at the terminals of cell increases while electrolysis is going on. Special experiments have shown that for a given current strength the potential of the platinized cathode remains quite constant for many hours. Moreover, by carefully keeping the current strength and the temperature of the electrolyte constant, it is possible to exclude any change of the e. m. f. due to a change of resistance of the electrolyte. Hence the change of the voltage at the terminals of the cell, which is observed under such experimental conditions, must be due to a change of the anode potential. If for measurements of the voltage a very well damped voltmeter of large internal resistance is used it is possible to measure with sufficient accuracy the difference of potential which the platinized anodes have against the cathodes charged with hydrogen, immediately after interruption of the current. The value of the counter electromotive force thus found will be called $p$ in the following. For smooth anodes the same determination cannot be carried out with certainty on account of their very small capacity.

Table I gives the results of experiments, which show the course of the phenomena more in detail. The current strength was 0.5 amp., which is equivalent to a current density of 0.017 amp. per sq. cm; the temperature was kept at 10° C.

The results of these experiments are also represented by the curves in figure 1, in which the drawn-out lines relate to platinized anodes, and the dotted lines to smooth anodes.

According to these experiments, platinum anodes at which oxygen is developed show special peculiarities in two directions. First, we see that their potential increases considerably during the course of electrolysis. Second, we see that smooth platinum anodes assume a much higher potential than platinized anodes. In the following these two sides of the phenomenon will be scrutinized somewhat more closely.

### THE INCREASE OF THE POTENTIAL AT ANODES AT WHICH OXYGEN IS DEVELOPED.

At a *platinized* anode the potential increases first quickly, then more slowly, but even after considerable lapse of time this increase does not stop completely. The potential thereby reaches values which are about 0.4 volt above that at the beginning of the experiment.

This increase of potential cannot be caused by a gradual impoverishment of the anions required for discharge, because the change of concentration which occurs until a stationary condition is reached, and which depends on the current strength used, requires only a fraction of a minute to become complete at electrodes at which no oxygen is developed, as, for instance, in the electrolysis of potassium iodide, and then the anodic potential remains quite constant for a considerable

[9] Zeitsch. f. Inorgan. Chemie., v. 3, 4, 86.
[10] Zeitsch. f. Electrochem., v. 8, p. 515.

TABLE I.

| Experiment 1. | | | Experiment 2. | | Experiment 3. | | | Experiment 4. | |
|---|---|---|---|---|---|---|---|---|---|
| Electrolyte 2n. $H_2SO_4$. | | | | | Electrolyte 2n. NaOH. | | | | |
| Platinized Anode. | | | Smooth Anode. | | Platinized Anode. | | | Smooth Anode. | |
| Time After the Beginning of the Experiment. | Voltage at the Terminals. | P in Volts. | Time After the Beginning of the Experiment. | Voltage at the Terminals. | Time After the Beginning of the Equipment.. | Voltage at the Terminals. | P in Volts. | Time After the Beginning of the Experiment. | Voltage at the Term'ls |
| Immediately after closing of the circuit. | 1.7 | ------ | Immediately after closing of the circuit. | 2.27 | Immediately after closing of the circuit. | 1.8 | ---- | Immediately after closing of the circuit. | 2.20 |
| ½ minute | 1.79 | ---- | ½ minute | 2.28 | ½ minute | 1.84 | ---- | 1 minute | 2.41 |
| 1 " | 1.80 | ---- | 1 " | 2.30 | 1 " | 1.855 | ---- | 2 " | 2.49 |
| 2 " | 1.82 | ---- | 2 " | 2.31 | 2½ " | 1.88 | ---- | 3 " | 2.57 |
| 3 " | 1.84 | ---- | 6 " | 2.33 | 4 " | 1.89 | ---- | 4 " | 62.3 |
| 4 " | 1.85 | ---- | 10 " | 2.34 | 6 " | 1.91 | ---- | 6 " | 2.72 |
| 5 " | 1.86 | ---- | 23 " | 2.36 | 10 " | 1.94 | ---- | 10 " | 2.77 |
| 15 " | 1.91 | ---- | 33 " | 2.36 | 23 " | 1.99 | ---- | 20 " | 2.88 |
| 33 " | 1.94 | ---- | 53 " | 2.37 | 30 " | 2.01 | ---- | 60 " | 2.92 |
| 39 " | 1.95 | 1.74 | 80 " | 2.39 | 50 " | 2.04 | ---- | 75 " | 2.93 |
| 70 " | 1.99 | 1.78 | 2 hours | 2.40 | 60 " | 3.05 | --- | 2 hours | 2.91 |
| 2 hours | 2.02 | ---- | 4 " | 2.41 | 80 " | 2.07 | 1.84 | 3 " | 2.90 |
| 4 " | 2.06 | 1.84 | 5 " | 2.42 | 4 hours | 2.13 | 1.90 | 6 " | 2.90 |
| 6 " | 2.07 | ---- | 6 " | 2.41 | 6 " | 2.15 | ---- | 7 " | 2.89 |
| 7 " | 2.07 | ---- | 7 " | 2.41 | 21½ " | 2.225 | 1.98 | 21 " | 2.89 |
| 8 " | 2.075 | ---- | 8 " | 2.415 | 25½ " | 5.23 | ---- | ---------- | ---- |
| 22 " | 2.107 | ---- | 22½ " | 2.415 | 59 " | 2.265 | 2.0 | ---------- | ---- |
| 26 " | 2.11 | ---- | ---------- | ---- | | | | | |
| 33 " | 2.115 | ---- | ---------- | ---- | | | | | |
| 46 " | 2.120 | 1.90 | ---------- | ---- | | | | | |

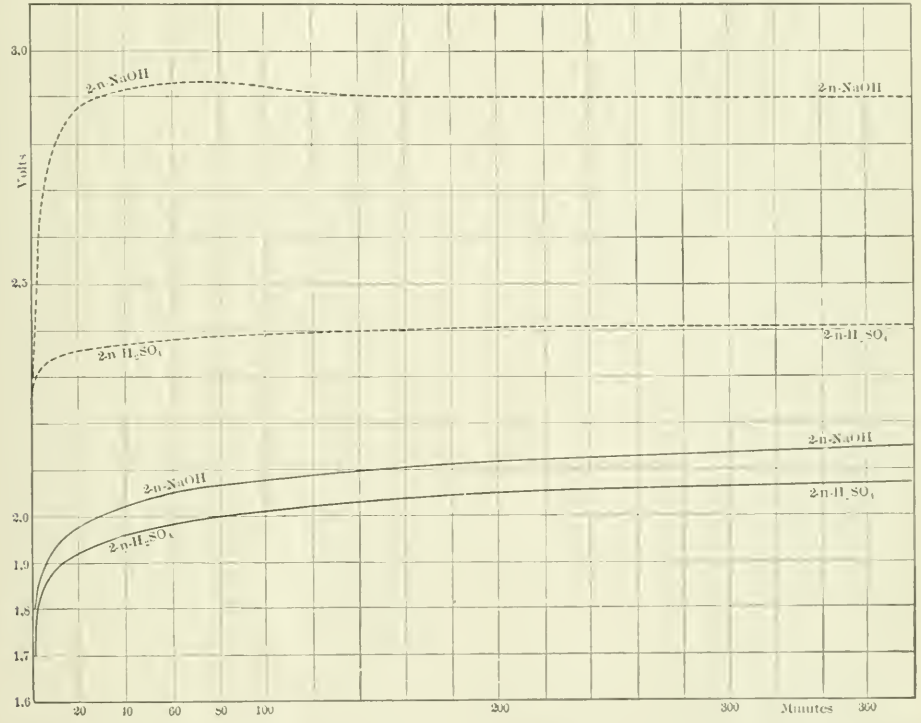
time. The fact proven by these experiments, that the development of oxygen at a platinized anode requires an increasing amount of work while electrolysis is going on, must be attributed to a gradually increasing change *in* the platinized electrode.

The following observations confirm this: If the current is interrupted after electrolysis has been carried on for some time, and if the circuit is closed again a few seconds later, electrolysis commences at the same potential at which it had stopped; and even, after an interruption of several minutes, when the circuit is closed again, the potential is only a little below the former one, and this is soon reached again. One may even take an electrode which is polarized to a high anodic potential, out of the electrolysis and wash it off, to use it again as an anode in another solution; when electrolysis is then started in the new solution the anodic potential is a few tenths of a volt higher than would be the case if a freshly platinized anode had been used. But if an anodically polarized electrode is used as cathode until hydrogen is generated at it, and is then made again anode, it acts like a freshly platinized plate.

Therefore, we may imagine that during electrolysis small parts of the anodically generated oxygen are absorbed by the platinum black and are stored in it at a gradually increasing pressure. After the external force has ceased, this oxygen is only slowly given off again. The condition in which the oxygen is stored in the platinum black is not necessarily that of a simple gaseous solution; such a solution would have to be assumed to be under enormous pressures. It is very well possible that we have here a platinum-oxygen compound, which, however, must then be assumed to be dissolved in platinum black in steadily varying concentration; this assumption is necessary in view of the *steady* increase and decrease of the potential.

Remarkable is the following fact which shows that only a small quantity of oxygen can be present in the platinum black. The increase of potential of a platinized anode in caustic soda solution takes place in an almost unchanged manner, if, for example, by means of addition of sodium formate 90 per cent. of the anodic oxygen are prevented from being liberated and are used for oxidizing purposes. If, on the other hand, the anodic potential is kept at a value not sufficient for the development of any oxygen, by means of a suitable depolariser, as, for instance, concentrated oxalic acid solution, then the potential does not change even by 0.01 volt in one hour.[11]

The temperature has a material influence on the increase of the potential of a platinized anode at which oxygen is developed. The lower the temperature, the greater is the increase of the anode potential in the course of time. Under otherwise the same conditions as in experiment 3 of the above




CURVES OF THE POTENTIAL OF SMOOTH AND PLATINIZED PLATINUM ANODES AT WHICH OXYGEN IS DEVELOPED

table, but at a temperature of 75° C., the anodic potential was found to rise by 0.13 volt in the first two hours, and then to remain constant, therefore, the increase of potential was only one-third of that which took place at 10°.

At a *smooth* anode the anodic potential also arises quite considerably during the course of electrolysis. This increase, however, takes place much more quickly than at a platinized anode, and the anodic potential soon assumes a value which remains constant for a long time. But if the current is now interrupted and closed again right away, the voltage at the terminals of the cell is near its initial value, and about the same time, as before, must elapse before the voltage reaches

[11] F. Salzer, Zeit. f. Elektrochemie, v. 8, p. 809.
Foerster and Mueller, Zeit. f. Elektrochemie, v. 9, p. 265.

again the value observed before interruption of the current. Whether this fact is solely due to the very small capacity of smooth platinum anodes as compared with platinized anodes, or whether there are special phenomena taking place here besides those which cause an increase of potential at platinized anodes, is still an open question.

THE DIFFERENCE BETWEEN THE POTENTIALS OF PLATINIZED AND SMOOTH PLATINUM ANODES WITH OXYGEN DEVELOPMENT.

Of considerable importance is the second property of platinum anodes at which oxygen is developed, namely, that for the same strength of current the voltage drop at a smooth anode is much greater than at a platinized anode. The difference between the potentials which both kinds of anodes assume in the above-mentioned experiments increases at the beginning to very considerable values. These, however, become later somewhat smaller, when during the course of electrolysis the potential of the platinized anode approaches its maximum value. This difference between the potentials of both kinds of anodes was found to have the following values: At a current density of 0.017 amp. per sq. cm, after 10 to 11 amp.-hours it was

in 2n $H_2SO_4$ 0.308 volt.
in 2n NaOH 0.665 volt;

at a current density of 0.067 amp. per sq. cm, after 8 amp.-hours it was

in 2n $H_2SO_4$ 0.46 volt,
in 2n NaOH 0.75 volt.

The difference between the potentials depends, therefore, upon the nature of the electrolyte and the current density; and an increase in temperature seems to decrease it. It is seen that this difference in potential is considerably larger than 0.2 volt, which is the difference between the potentials required for the beginning of the generation of oxygen at platinized and smooth platinum anodes and must, therefore, not be identified with it, although it is probable that the same or similar causes are at the bottom of both facts. What these causes are cannot yet be stated. We can only assert that it is probable that the difference of the work necessary for the formation of gas bubbles as smooth and at rough surfaces can only, to a small degree, cause the large excess of the voltage required for developing oxygen at a smooth anode over that required at a rough anode.

The question of the nature of this strong increase in potential at a smooth platinum anode becomes of special interest if it is formulated as follows: When oxygen is developed at a smooth platinum anode, is it necessary to overcome a considerable transition resistance at the electrode so that the surplus of voltage consumed corresponds merely to a development of heat, or is it wholly or partly available for performing chemical work?

That the latter is the case, might be concluded from the fact that quite a number of anodic reactions are dependent upon the presence of smooth platinum electrodes, and either do not take place at all or with a very small current efficiency at platinized electrodes. Such processes are, for instance, the formation of persulphuric acid and its salts, the formation of ethane in the electrolysis of acetates or the electrolytic production of perchlorates. All these are reactions which go on well if carried out with a high anodic current density and a high concentration of certain anions, whose discharge is essential for the reaction:[13]

$$2\,HSO'_4 + 2\,F = H_2S_2O_8$$
$$2\,CH_3CO'_2 + 2\,F = C_2H_6 + 2\,CO_2$$
$$\left.\begin{array}{l} 2\,ClO'_3 + H_2O + 2\,F = ClO'_4 + ClO_2 + 2\,H^{\cdot} + O \\ ClO'_2 \quad O = ClO'_3 \end{array}\right\}$$

Lately it has been made probable through experiments by W. Oechsli in the Dresden laboratory that the mechanism of the electrolytic formation of perchlorate is expressed by the latter equations.

It requires, however, generally much more work to discharge acid anions containing oxygen than OH′ ions, and this is probably also true when they are present in such a small concentration as in water. At smooth anodes the reactions take place in a very small space, and the concentration of the OH′ ions will be very quickly diminished by the acidification accompanying the discharge of the anions, so that the current then depends on the discharge of the other anions. On the other hand, at a platinized anode such a strong diminution of the concentration of the OH′ ions will not take place at all, and the discharge of acid anions will occur to a small degree only or not at all. It is possible to obtain the same result at a smooth anode by adding a small amount of alkali to the solution; and, in fact, from the experiments made with the three reactions mentioned above, it is possible to state, as a rule, that an anodic process which gains considerable extent only at smooth but not at platinized platinum anodes, can be wholly or partly suppressed at a smooth anode if a small quantity of alkali is added to the electrolyte. In the latter case there is not the same diminution of anode potential as with platinized anodes; therefore, the phenomena in question cannot altogether be assumed to be due to the higher potential at the smooth platinum anode. For the explanation of the influence of smooth platinum anodes on those phenomena, it is sufficient to assume that there is a much smaller OH′ concentration and a larger concentration of acid anions at smooth than at platinized anodes; hence this is an analogy to the difference above mentioned in the electrolysis of potassium iodide with smooth and with platinized anodes, and it still remains to be decided whether special electrochemical processes may be caused by the specially high potential at a smooth platinum anode.

The above described behavior of platinum anodes at which oxygen is developed has already been found to be capable of practical application for various purposes. A few examples may be given.

ALKALI CHLORIDE ELECTROLYSIS WITH SMOOTH AND PLATINIZED PLATINUM ANODES.

If neutral strong alkali chloride solutions are electrolyzed for manufacturing hypochlorites and chlorates, and if the anode is platinized, nearly chlorine ions alone are discharged at it, with a current efficiency of about 99 per cent. besides very small quantities of oxygen. The anodic potential is determined by the separation of chlorine, and reaches very soon a constant value which depends on the current density.[14] The chlorine developed at the anode reacts in the electrolyte with the hydroxide coming from the cathode, and the formation of hypochlorite results. When the ClO anions, thereby produced in the electrolyte, have reached a certain concentration in processes. They are thereby discharged, and react according to equation:[15]

$$6\,ClO^{\cdot} + 3\,H_2O + 6\,F = 6\,H^{\cdot} + 2\,ClO'_3 + 4\,Cl' + 3\,O.$$

So that chlorate is formed in the solution and oxygen is developed at the anode.[16] The oxygen development quickly becomes more brisk and soon reaches a value corresponding to about one-third of the current strength. In spite of this, however, the anodic potential does not rise; only at a high current density it rises very little.

This fact is very remarkable. The free hypochlorous acid, which was already present at the anode, besides chlorine, is a strong oxidizing agent, so that before oxygen escapes freely, the hypochlorous acid has already produced a certain oxygen pressure in the anode. For, according to Nernst, an oxidizing agent impresses its oxidation potential on the anode by producing in or on it an oxygen pressure corresponding to its nature.

[13] In these equations and those which follow later in this article, F. (abbreviation of Faraday) represents the electric charge of a positive monovalent gramion, about 96,600 coulombs.

[14] Foerster and Mueller, Zeit. f. Elektrochemie, v. 8, pp. 520 and 525.

[15] Concerning the meaning of F., see the foot note 13.

[16] Foerster and Mueller, Zeit. f. Elektrochemie, v. 8, p. 667.

In the present case, the anode potential, while determined in the first line by chlorine development, has a value sufficient for the development of oxygen, if, besides the Cl′ ions, a sufficient number of OH′ or ClO′ ions can reach the anode. Should the anode potential increase, due to the development of oxygen, then if solution and electrode shall continue to be in equilibrium, it would be necessary that the potential of the hypochlorous acid, *i. e.*, its concentration at the anode, also increases. But this acid is the less stable, the higher its concentration, hence a considerable increase of concentration is impossible. It seems that in this way the oxygen is prevented from increasing the anode potential in the otherwise usual manner.

If, however, the electrolysis is carried out with a *smooth* anode, say with a current density of 0.067 amp. per sq. cm, the anodic potential, which remains constant during the first minutes, is only about 0.12 volt above that observed at a platinized anode, that is about as much as is due to the greater impoverishment of chlorine ions, which takes place at a smooth anode. But the potential of chlorine against very dilute chloride solutions is very nearly equal to the anodic potential required for the development of oxygen from a weak acid solution (as which we may consider an aqueous solution containing free gaseous chlorine on account of the equilibrium $Cl_2 + H_2O = H^+ + Cl^- + HOCl$). Therefore, as soon as the dilution of the chlorine ions at the anode has reached a certain degree, oxygen also appears, probably first by the discharge of the OH′ ions of the water, but very soon also by the discharge of ClO′ ions. It has been shown by Lorenz and Wehrlin[17] that this development of oxygen raises the anodic potential very soon considerably above its initial value, and, if compared with the platinized anode, it causes again an increase of potential of about the value determined above for caustic soda. For saturated sodium chloride solution at 10° it was found to be at a current density of 0.067 amp. per sq. cm. after 10 amp.-hours 0.82 volt, and a current density of 0.017 amp. per sq. cm after 11 amp.-hours 0.75 volt. In this case there is no equilibrium between the oxidation potential of the solution and the oxygen present in the electrode. One might conclude that a direct contact of the solution with the electrode is prevented by an intermediate layer of oxygen, and that it is its resistance which causes the great voltage loss at smooth anodes at which oxygen is developed.

In spite of the great difference in anodic potential, the replacement of a platinized anode by a smooth one does not produce any other essential change in the course of the electrolysis of alkali solutions. Especially the yield of chlorate per ampere hour at a platinized and smooth anode is the same as long as the electrolyte remains neutral, if the cathodic reduction of the hypochlorite is made imposible, according to E. Mueller's method,[18] by adding a small amount of chromate to the electrolyte. The formation of hypochlorite, produced by the current in the solution during the first part of the electrolysis, takes place with somewhat lower ampere-hour efficiency, and in a somewhat smaller concentration at a smooth anode than at a platinized anode, on account of the very early development of oxygen at a smooth anode; at a platinized anode a solution of 45 g bleaching chlorine was obtained in 1 liter. If, however, the watt-hour efficiency of the formation of chlorate at both kinds of electrodes is compared, it is at the smooth anode only 75 per cent. of that at the platinized anode.

The latter has still another special advantage, if a slightly acidulated chloride solution is used. As mentioned above, when a platinized anode is used, the concentration of hypochlorite can become pretty high in the electrolyte, without any discharge of ClO′ ions, which takes place with generation of oxygen and with diminished current efficiency. If at this stage of the process so much hydrochloric acid is added to the electrolyte, that hypochlorous acid can be formed only from a part of the hypochlorite, then we have in the electrolyte the conditions which are most favorable for the formation of chlorate. This takes place according to the reactions:[19]

$$2HOCl + NaClO = NaClO_3 + 2HCl;$$
$$2HCl + 2NaClO = 2NaCl + 2HClO; \text{ etc.}$$

By this secondary formation of chlorate in the acidulated electrolyte, the hypochlorite produced by the current can be continually used up before it reaches the concentration required for the discharge of its anions. In this case the production of chlorate in the electrolysis of alkali chloride solutions takes place with an ampere-hour efficiency of about 98 per cent. and an energy yield of 1 gram chlorate oxygen per 12.5 watt-hours at a current density of 0.117 ampere per sq. cm.[20]

At smooth anodes the development of oxygen reaches a considerable extent with a concentration of hypochlorite in the solution, at which the secondary formation of chlorate does not take place with sufficient velocity to change the hypochlorite produced by the current into chlorate as quickly as it is formed. Until this point is reached, the anodic generation of oxygen already amounts to about 12 per cent. so that the ampere-hour efficiency of the formation of chlorate at smooth anodes cannot be increased much above 88 to 89 per cent.

The conditions at a platinized anode represent nearly the ideal conditions for alkali chloride electrolysis. Whether this method of working can be used without modification in practice on a large scale, or whether it will only be possible to try and come as near as possible to these results in another way, must be left undecided. Under all circumstances it has to be remembered that platinized anodes can only find practical application in the electrolysis of *sodium* chloride solutions; for the chlorate, which crystallizes from *potassium* chloride dilutions, covers the platinized anode with a diaphragm, which offers a considerable resistance, and between this diaphragm and the anode a very dilute chloride solution is electrolyzed with a brisk generation of oxygen.

Theoretically important was the study of the course of electrolysis of strongly alkaline solutions of chlorides at a platinized anode.[21] Oettel[22] has shown in 1894 that such solutions behave in a peculiar manner at a smooth anode; he found that in the same the current forms at most only traces of hypochlorite, chlorate being already formed from the beginning of electrolysis. This phenomenon, which is so different from those observed in the electrolysis of a neutral solution, has given rise to many hypotheses.

If we consider that in a 1 normal alkaline 3 normal sodium chloride solution, only 0.87 volt is required at a smooth platinum anode for the generation of oxygen by OH′ discharge, but —1.35 volt for the generation of free chlorine, we should think that in a normal alkaline solution of a chloride it should be impossible to get a chloride electrolysis. If it occurs, nevertheless, the reason must be that in the course of the development of oxygen, the potential required for the further development of the gas undergoes a considerable increase.

In fact it was found that at a freshly-platinized anode in a normal alkaline solution of an alkali chloride, an electrolysis of chloride, as shown by the formation of oxygen-chlorine compounds, was hardly perceptible at the start. But when the anodic potential increases during the passage of the current, more and more chlorine is discharged, which is immediately used up for the formation of hypochlorite on account of the depolarizing action of the OH′ ions at the anode. Very soon the relatively low value of the potential[23] required for the discharge of ClO′ at the anode is passed, and these anions are discharged again immediately after their formation, and there-

[17] Zeitsch. f. Elektrochemie., v. 6, p. 437.
[18] Zeit. f. Elektrochemie, v. 5, p. 469, and v. 7, p. 398.
[19] Foerster and Jorre, Journ. f. pract. Ch., v. 59, p. 53, and v. 63, p. 141.
[20] Foerster and Mueller, Zeit. f. Elektrochemie, v. 8, p. 11.
[21] Foerster and Mueller, Zeit. f. Elektrochemie, v. 9, p. 209.
[22] Zeit. f. Elektrochemie, v. 1, p. 474.
[23] Foerster and Mueller, Zeit. f. Elektrochemie, v. 8, p. 624.

by form chlorate, as stated above. With continuing increase of potential, the current efficiency of the formation of chlorate increases. The only difference between these phenomena and those at a smooth anode is that at the latter the increase of potential takes place quickly, and the chlorate appears from the start nearly as the only product of electrolysis with a nearly constant efficiency from the first stage of the experiment.

Anyhow, it is also generated in this case by the anodic discharge of $ClO'$ ions which have been primarily formed by the current, exactly as in a neutral solution. The apparently very great difference of both phenomena is that the beginning of the chlorate formation depends in a neutral solution upon the establishment of a certain concentration of $ClO'$ ions in the *electrolyte*, while in an alkaline solution it depends upon the moment at which the *electrode* assumes a certain condition which determines the value of the anodic potential.

ELECTROLYSIS OF SODIUM SULPHITE WITH PLATINIZED ANODES.

The described phenomena at platinized anodes may be summed up in the statement that it is possible, to enable these electrodes by previous anodic polarisation to perform electrochemical work which they could not perform otherwise; one might say it is possible to train them. A further case, in which one can utilize this possibility, is found in the electrolysis of sodium sulphite.[24] This acts as a strong depolariser for oxygen; even at a comparatively high current density a solution of sodium sulphite may suppress any anodic generation of oxygen and may hold the anodic potential below the potential necessary for such generation.

In this case at a freshly-platinized anode the sulphite is quantitatively changed to sulphate, according to the equation.[25]

$$SO_3'' + 2OH' + 2F = SO_4'' + H_2O$$

But if one uses as anode a plate of peroxide of lead, which has a comparatively high anodic potential, then only about half of the current furnishes sulphate, while the other part furnishes sodium dithionate according to the equation.

$$2SO_3'' + 2F = S_2O_6''$$

The same effect as on a lead peroxide anode may be obtained on a platinized anode, if it is charged previously for some time anodically with oxygen in a caustic solution and is used immediately afterwards for the electrolysis of sulphite solution. In such a solution, containing 380 grams $Na_2SO_3 \cdot 7H_2O$ in one liter, at a current density of 0.01 ampere per sq. cm. a freshly-platinized anode had the potential —0.32 to —0.35 volt against the normal hydrogen electrode, and at the same time sulphate was formed with 100 per cent. current efficiency. But when the same anode was used first as anode for 40 hours in a very pure caustic soda solution, and was then employed for the electrolysis of the sulphite solution, it showed, at a current density of 0.01 ampere per sq. cm., the potential of —0.64 to —0.78 volt and 47 per cent. of the current formed dithionate and 53 per cent. formed sulphate. By short cathodic polarization the electrode lost almost entirely the power to form dithionate.

USE OF PLATINIZED ANODES IN QUANTITATIVE ANALYSIS BY ELECTROLYSIS.

Another use of platinized electrodes, which has recently been developed by P. Denso,[26] refers to an essentially different field. The quantitative determination of copper by electrolysis would be most simple, if one would connect the poles of an accumulator directly to the binding posts of the platinum electrodes, which dip into the copper solution. Its e. m. f. of 2 volts is sufficient to deposit the copper quantitatively from a sulphate solution, while the separation of the metals Ni, Co, Fe, Cd, Zn, which so often accompany the copper, is thereby made impossible, and a quantitative separation of the copper from the latter might be obtained at the same time. As with such an arrangement only a small current passes through the electrolyte, the evolution of gas at the electrodes is so small that the electrolyte does not spatter or splash in such manner as to disturb the analysis, and the electrolysis does not need watching. The copper is deposited in bright red, dense form, without having nitric acid in the solution; at the end of the deposition of copper it is therefore possible to take the cathode out of the electrolyte, without having to fear any loss, and to wash the solution adhering to it back into the electrolyte, in order to determine another metal present in the electrolyte by electrolysis. For this purpose it is then only necessary to make such additions to the electrolyte as are required for the intended metal-deposition, and to use an e. m. f. higher than 2 volts.

While this extremely simple method of working has already been proposed by Freudenberg[27] ten years ago, it has up to the present not been introduced into analytical practice; the essential reason seems to have been that the current which passes through the electrolyte in this case drops very soon to such a small value that the determination of copper requires a comparatively very long time. It takes at least eight hours to deposit 4.25 grams of copper on a Winkler[28] wire gauze electrode against the usual spiral of smooth platinum wire with the current from one accumulator, and electrolysis is best carried out over night.

But as the voltage of decomposition of a normal copper sulphate solution is only 1.4 volts, and as the resistance of the solution can easily be reduced by sulphuric acid, it is somewhat difficult to perceive why, with this arrangement, only such a small current passes through the solution. The reason is that, on account of the impoverishment of copper near the cathode, and more especially on account of the increase of potential at the smooth anode, the polarization e. m. f. of the cell during the passage of the current is soon much nearer the value of 2.0 volts than the theoretical minimum of 1.4 volts.

The counter electromotive force of the cell is decreased and the current strength therefore increased, if a platinized anode is used. Moreover, if we fasten it to the clapper of an electric bell, which is arranged without the bell on the stand for electrolysis, we get at the same time a stirring device which diminishes the impoverishment of copper at the cathode and also contributes to an increase of current strength. It is thus possible to deposit with the current from one accumulator 0.1 gram of copper quantitatively in 1½ hours, and 0.25 grams in 3½ to 4 hours. The possibility is thus given to introduce this most simple and most rational method of quantitative determination of copper into practice.

CONCLUSION.

The investigation of the generation of oxygen at platinum anodes, which was apparently of theoretical value only, has thus already proven useful in several directions, and these researches may be expected to give still more useful results in future, when the electrolytic oxidation of organic compounds will be studied as closely as electrolytic reductions have been studied. The electrolytic oxygen which is developed at platinum, the material mostly used for anodes, possesses an extremely energetic oxidizing action. This is already shown by the fact that it often contains ozone. It is, therefore, capable of oxidizing completely organic bodies of high stability. For instance, pyridine is destroyed at a platinized anode, and this occurs the more rapidly the higher the potential becomes. A conclusion to be drawn from the theory which may at first sight sound paradoxical, but which is proven to be correct by experiment, is that at elevated temperatures when the increase of anodic potential is very much smaller than in the cold, the pyridine is less susceptible to electrolytic oxidation than in the cold. If one wants to use electrolytic methods for oxida-

[24] F. Foerster and A. Friessner, Ber. Deutsch. Chem. Ges., v. 35, p. 2514.
[25] Concerning the meaning of F., see foot note 13.
[26] Zeit. f. Elektrochemie, v. 9, p. 463.
[27] Zeit. f. Physik. Chem., v. 12, p. 97.
[28] Ber. Deutsch. Chem. Ges., v. 32, p. 2192.

tion purposes, it will be necessary to keep the potential necessary for the appearance of oxygen at a low value, if we have not to do with strongly depolarizing reducing agents which suppress the generation of oxygen completely.

As Coehn and Osaka emphasize, their observations, mentioned before, furnish pointers to perhaps valuable new methods, and the prospect becomes still brighter if the use of peroxide electrodes such as $Ni_2O_3$, $Co_2O_3$, $MnO_2$, $ClO_2$, etc., is taken into consideration. Here is still a wide field open for investigation which promises success.

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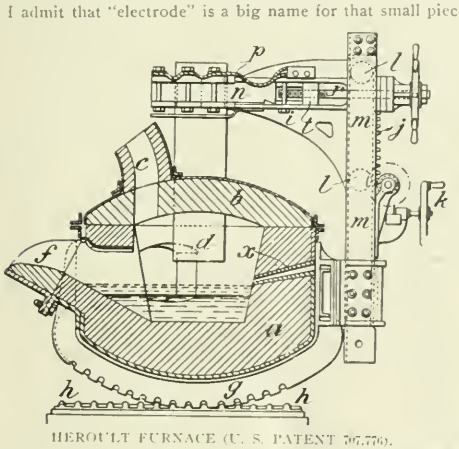
## ELECTRIC STEEL PROCESS.

By P. L. T. Heroult.

In 1899 I was led to find out some process for making what is generally known as low carbon ferro-chromium. After some unsuccessful experiments I came to the conclusion that the only way of manufacturing the above-named article was to do away with the usual form of electrical crucible. Therefore, having coupled two of my dynamos in series, I made a furnace in which the current jumped from the end of the electrode to the metal to be heated, in the usual form of an arc. But instead of leaving said metal through the bottom or sides of the crucible, it jumped again from the metal to the tip of another electrode, parallel to the first one. By this very simple arrangement the furnace at once became an ordinary receptacle or container, being entirely free from any electrical function. I must say that this arrangement had been thought of by others for solving some other problems.

However, the system would have been unsuccessful if it had not been for the method of regulating the arcs. This was a little more troublesome, but I got over the difficulty by means of a third "electrode," consisting of a piece of wire in contact with the metal to be heated and connected to one terminal of each of two voltmeters, while the other terminals are connected to the poles of the dynamo.

I admit that "electrode" is a big name for that small piece



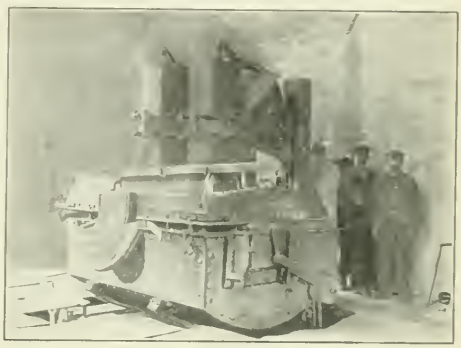

HEROULT FURNACE (U. S. PATENT 707,776).

From the carbon electrodes *d* the arcs jump to the metal. The bottom of the furnace is arched, and cogs on rails *g* engaging with cogs on rails *h* are arranged for effecting the tilting. For further details, see Electrochemical Industry, 1902, p. 63.

of wire, inasmuch as it is burnt away as soon as the furnace gets hot, but then it is replaced by the conductivity of the walls and bottom, which allow, owing to their great sectional area, a current of a few milliamperes to pass. In fact, all the regulation is automatic, and it is almost indispensable that it should be so, on account of the danger of spoiling the heat, by dissolving carbon from the electrodes.

This apparatus was extensively used for making low carbon ferrochromium for some months. When it was first tried for iron, the efficiency was found very low; the apparatus had to be completed by a cover or lid so as to prevent the heat from radiating and being wasted.

As it stands in its present shape it looks very much like a Wellman furnace with two electrodes sticking in through holes in the cover. The furnace itself is built on two rockers,

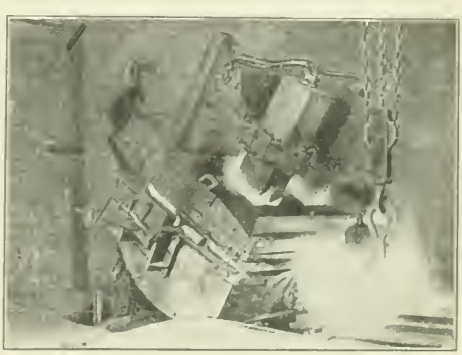


400 HP HEROULT FURNACE (LA PRAZ, 1903).

and by means of a hydraulic ram can be tilted so as to pour out its charge, "about three tons."

Having in my hands this instrument, I began, as might have been expected, to make bad use of it, viz.: trying the old problem of smelting steel or iron direct from the ore. This was, of course, a failure, the above-described furnace proving to be perfectly inadequate to that kind of work, chiefly on account of the corrosion of the walls and uncertainty of the final results of the operation. I decided, therefore, to divide the difficulty in two: first making cast-iron or pig, and afterwards treating said pig in the steel furnace. But now another difficulty arose, which was that we lost the principal advantage of the furnace by attempting to refine or oxidise part of the elements of the charge in an apparatus which was much more suited to melt down a charge in the absence of oxygen or oxidising agents.

The cast-iron problem was solved by means of another



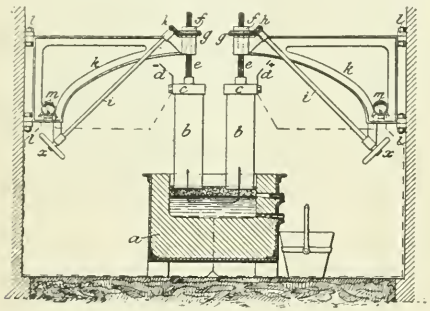
400 HP HEROULT FURNACE (LA PRAZ, 1903).

furnace, which did its work to the extent of 250 tons, which were sold. However, the process was laid aside for the time being, as more interesting for mine and hydraulic-power owners than for my company.

I then devoted my time and attention to the steel process, which proved to be of more immediate interest.

As it stands now it is chiefly used in the following way:

A charge of scrap iron, mixed or not mixed, with pig, is melted either in the steel furnace itself or poured into it in the molten state from a ladle or from the fore hearth of a Wellman furnace or from a converter, the principal condition being that the molten metal should be suroxidised or overblown and free from slag. It is then covered with an artificial slag and submitted to the action of the current, which has no other object but to heat it up without any intervention of flame or oxidising agent of any kind. This enables me, by pouring out the first slag and charging new fluxes, to wash out all the impurities of the metal; by adding carbon and other ingredients a perfect deoxidation is obtained, and as a matter of fact the steel made by this process holds the record for purity. Perfectly deoxidised, traces of phosphorus and sulphur, all other elements at will, or to order, as one might



HEROULT FURNACE (U. S. PATENT 721,703).

The voltmeters *m* are in shunt with the two arcs between the electrodes *b* and the metal. For further details, see Electrochemical Industry, 1903, p. 287. Another furnace of Héroult is illustrated in the Analysis of Current Electrochemical Patents of this issue.

say, and all this made out of the most common kind of raw material; this is the result of the process in its present form.

I may add that outside of trials there have been made at this date about 1500 tons, of which 300 tons were produced in Sweden by the Aktiebolaget Héroults Elektriska Stal. This metal is tool steel, equal in quality to the best grade of crucible steel, and sold as such. The process is going to be applied to a large Thomas works, where electricity will be produced by a blast-furnace gas engine. The output of electrically treated metal is in France 6 to 7 tons a day, working on cold scrap; in Sweden, about the same, and with the Thomas combination it will reach 150 tons every twenty-four hours with one furnace, 5 ton heats, using 600 h.p. The consumption of electrodes is insignificant.

## EXPERIMENTAL DETERMINATION OF THE SINGLE POTENTIALS OF THE ALKALI METALS, SODIUM AND POTASSIUM.

By Harrison Eastman Patten and William Roy Mott.

Nearly a century ago Davy discovered the alkali and alkaline earth metals. He isolated them by electrolysis of their fused salts. As another phase of the same subject, he determined an electrochemical series,[1] using dilute acids, as follows: + Potassium, barium, zinc amalgam, zinc ammonium-amalgam, cadmium, tin, iron, bismuth, antimony, lead, copper, silver, palladium, tellurium, gold, platinum, iridium and rhodium.

The potentials of alkali and alkaline earth metals have been obtained by amalgamating and determining the difference of potential between the amalgam and the solution used. The conception of a battery in which the anode is an alkali metal is not new. Goodman,[2] in 1847, used potassium amalgam as the plus electrode of a primary cell, which gave a total pressure of 3.23 volts.

Much excellent work has been done recently[3] upon the electromotive force developed by amalgams, of various concentrations, various metals and against different electrolytes. Still later, M. Sack[4] has determined the electromotive force of various amalgams, sodium alloys[5] and of sodium and sodium amalgam against lithium chloride dissolved in methyl alcohol at — 80°C. His references to the literature of the subject are very complete.

We have determined the single potentials of potassium and sodium against various electrolytes, both aqueous and non-aqueous. The electromotive force was measured by the Poggendorf compensation method, using as a zero instrument a Queen galvanometer, for which three-fourths scale division equals one-millionth of an ampere. A normal electrode whose voltage was taken as — .56 served as a half cell, to which connection was made through a strip of filter paper which had been saturated with the solution to be used. An asbestos shield afforded protection from fire, and the explosions which necessarily accompany the contact of potassium and sodium with water. The ignition of the hydrogen evolved by the metal was delayed by allowing only a small surface of metal to come in contact with the electrolyte. This afforded sufficient time to take several readings of the electromotive force. The single potential of metallic sodium and potassium, as experimentally determined by us, are given in the following table, together with some calculations of the theoretical single potentials.

Table I.—*Experimental Single Potentials.*

| Electrolytes. | Potassium. | Sodium |
|---|---|---|
| KI in Acetone (Sat.) | 2.35 V.<br>2.34 | 2.14 V.<br>2.14 |
| NaI in Acetone (Sat.) | 2.26<br>2.555<br>2.31<br>2.31 | 2.18<br>2.16<br>2.22<br>2.14 |
| LiCl in Acetone (Sat.) | 2.35<br>2.31 | 2.14<br>2.14 |
| LiCl in Propyl Alcohol (Sat.) | 2.23 | 2.05 |
| LiCl in Ethyl Alcohol (Sat.) | 2.29<br>2.29 | 2.16<br>2.155 |
| LiCl in Pyridine (Sat.) | 2.20<br>2.18<br>2.12<br>2.10 | 2.06<br>1.94<br>1.91<br>2.06 |
| n KCl in Water | 2.35<br>2.33<br>2.31<br>2.31 | 2.20<br>2.18<br>2.14<br>2.20 |
| n NaCl in Water | 2.32<br>2.29 | 2.14<br>2.13 |
| 39% LiCl in Water (Nearly Sat.) | 2.30<br>2.29 | 2.18<br>2.12 |

*Theoretical Single Potentials.*

| | | |
|---|---|---|
| Chlorides | 2.38 V. | 2.18 |
| Sulphates | 2.39 | 2.19 |
| Nitrates | 2.36 | 2.15 |

The above theoretical single potentials were calculated as follows: First, a calculation of the voltage of decomposition was made (from the heat of formation in dilute aqueous solution) for a chloride of some metal, such as zinc chloride, in the following table. From this value (2.44 volts) subtract the single potential of zinc[6] (as given by Neumann[6] for zinc in zinc chloride), + 0.503 volts and there remains — 1.94 volts as the single potential of chlorine.

[1] G. Gore, *Electrolytic Separation of the Metals*, p. 56.
[2] Alfred Daniell, *Physics*, p. 623 (1893).
[3] V. Türin, *Zeit. Phys. Chem.* 5, 340 (1890).
G. Meyer, *Zeit. Phys. Chem.* 7, 221 (1891).
H. P. Cady, *Jour. Phys. Chem.* 2, 551 (1898).
[4] *Zeit Anorg. Chem.* (1903) 34, 226, 252.
[5] F. Haber, *Trans. Am. Elect. Chem. Soc.* (1902) Vol. II., p. 189.
[6] *Zeit. Phys. Chem* XIV., 229 (1894).

TABLE II.

| I. | II. | III | IV. |
|---|---|---|---|
| $ZnCl_2$ | 2.44 | + 0.503 | — 1.94 |
| $FeCl_2$ | 2.16 | + 0.087 | — 1.97 |
| $CoCl_2$ | 2.05 | — 0.015 | — 2.065 |
| $NiCl_2$ | 2.03 | — 0.020 | 2.05 |

Similar calculations gave the above values for the single potential of chlorine, which may be taken as — 2.00 volts and which agrees well with the experimental determinations. And in like manner the single potential of the radical $SO_4$ is found to be — 1.85 volts, and that of $NO_3$ to be — 1.80 volts.

Second, the decomposition voltages of chlorides, sulphates and nitrates of potassium and of sodium were calculated from their heats of formation in dilute aqueous solution. These values are given below.

TABLE III.—*Theoretical Single Potentials of Potassium and Sodium.*

| | POTASSIUM. | | | SODIUM. | | | |
|---|---|---|---|---|---|---|---|
| | D. P. | Pot. Rad. | Pot. K. | D. P. | Pot. R d. | Pot. Na. | Pot. K—Na. |
| Chloride | 4.38 | — 2.00 | + 2.38 | 4.18 | — 2.00 | + 2.18 | 0.20 |
| Sulphate | 4.24 | — 1.85 | + 2.39 | 4.04 | — 1.85 | + 2.19 | 0.20 |
| Nitrate | 4.6 | — 1.80 | + 2.36 | 3.95 | — 1.80 | + 2.15 | 0.21 |

In the above table, D. P. is the voltage of decomposition calculated from the heat of formation, as stated previously. Pot. Rad. is the single potential of the radical, as calculated in the previous paragraph. Pot. K, Pot. Na are the single potentials of potassium and of sodium, respectively. And Pot. K — Na is the difference in volts between the single potentials of potassium and sodium.

The following considerations indicate the reliability of our experimental determinations. Each of the values given for the single potential in Table I was obtained independently. Determinations were (1) repeated on the same specimen of metal, (2) on different specimens, (3) on fresh portions of the solutions and (4) on different days. (5) The single potential of zinc against normal potassium chloride was used as a check against our normal electrode. (6) Two observers did the work. (7) An examination of Table I. shows that the single potential of potassium is higher than that of sodium, and that, in general, the magnitude of this difference is of the same order as the difference observed between their theoretical single potentials in Table III. (8) Calculations based on thermal data confirm the experimental values. (9) The relative rate of action of the various solutions upon potassium and sodium varies greatly, and yet the single potentials are comparable throughout the whole series given in Table I. (10) A check as to the probable magnitude of the contact potential difference between the organic solution and the aqueous solution can be obtained from the work of Kahlenberg.[7] Consult further H. R. Carveth, on "Single Differences of Potential."[8]

From the preceding considerations, and from Table I, it is seen that the harmony observed between the theoretical single potentials and the experimentally determined values is greater than is to be expected from the statement on page 226 in *Le Blanc*.[9] "The value of magnesium, aluminium, and manganese, the water-decomposing metals, are only to be considered as lower limits, their action upon the water causing them to diminish immediately after introduction of the electrode." Magnesium and aluminium both have, as a rule, experimental values of the single potential some three-fourths of a volt lower than the theoretical values. Burgess and Hambuechen[10] explain this discrepancy as being due to the formation of a film upon the surface of the metal. Other analogous cases are those of chromium and zinc.[11] This explanation appears to us to be the true one. In electrolyzing lithium[12] out of pyridine, under certain conditions, we obtained a film similar to those present in the above cases. Sodium can be easily melted under pyridine, but soon coats over with a film. This suggests a reason why the lowest values in Table I are those for pyridine solutions.

Thus, the results in this paper strengthen the view that metals which give potentials lower than the theoretical do so rather because of the formation of a film upon them than because the metal decomposes the solution with liberation of hydrogen. The oxides and hydroxides of the alkalies, as well as their alcoholates, are soluble, so that we get no film, and the single potential observed is in fairly close agreement with the theoretical. At the same time, the hydrogen undoubtedly exerts some influence, but that this is small can be seen from the values of the single potential actually obtained.

In our work on lithium[13] we have found a fairly uniform decomposition voltage of four volts in various solvents. Subtracting from this the single potential of chlorine gives the single potential of lithium as + 2.0. But this is probably too low.

This work was done jointly in the Laboratories of Physical Chemistry and of Applied Electrochemistry, University of Wisconsin, Madison, Wis.

[7] Kahlenberg, *Jour. Phys. Chem.*, p. 379 (1899). Also, *Trans. Amer. Electrochem. Society*, 1902, Vol. II.
[8] *Jour. Phys. Chem.*
[9] *Electrochemistry.*
[10] ELECTROCHEMICAL INDUSTRY, January, 1903.

[11] Low values for zinc are given in the paper, Single Potentials of Zinc in Aqueous Solutions. *Trans. Am. Elect. Chem. Soc.*, Vol. III., 1903.
[12] Patten and Mott, The Role of Water in the Electrodeposition of Lithium from Pyridine and from Acetone. A paper read before the June meeting of the American Chemical Society, 1903.
[13] The Role of Water in the Electrodeposition of Lithium.
The Deposition of Lithium from Various Alcohols. A paper read before the June meeting of the American Chemical Society.

## PRODUCTION OF FLUORSPAR IN 1902.

From a report of Dr. J. H. Pratt to the United States Geological Survey, we gather the following information: There was a very large increase in the production of fluorspar in 1902 over that of 1901, which was partly due to its increased use for metallurgical purposes. The production in 1902 was 48,018 short tons, valued at $271,814, as compared with 19,586 tons, valued at $113,803, in 1901. Of this production 43,310 short tons, valued at $224,814, are reported to have been sold in the crude states, as compared with 15,450 short tons, valued at $77,500, in 1901, an increase of 27,860 tons in quantity and of $147,314 in value. There was an increase in price of both the crude and the ground fluorspar, the average price for the crude being $5.19 per ton, an increase of 19 cents over the 1901 price, and for the ground the price averaged $9.98, an increase of 76 cents over the 1901 price.

Besides the above production, there were 3520 tons of fluorspar mined, but not put on the market.

Cryolite, used in the manufacture of aluminium and sodium salts, is imported from Greenland. The imports for 1902 amounted to 6188 long tons, valued at $85,050, as compared with 5383 tons, valued at $70,880 in 1901, and with 5437 tons in 1900.

## PIONEERS OF ELECTROCHEMISTRY—VI.

### CHARLES S. BRADLEY

Mr. Charles S. Bradley will forever be cited among those few daring, impetuous pioneers in electrical engineering, who by putting into practice what they saw in visions and dreams have produced the phenomenal developments of recent years. Mr. Bradley is a broad man. While his name is justly mentioned among the pioneers of electrochemistry, the marks of his genius are found on all fields of electrical engineering. As Dr. M. I. Pupin, in a biographical sketch, once put it, Mr. Bradley was always connected with big things in electrical engineering, with huge experiments which proved huge successes.

Mr. Bradley was the engineer of the New York Edison Illuminating Company in 1881, and the success of this pioneer electric lighting company was due in a great measure to his inventive resources.

But the field of this company was too small for two such men, like Edison and Bradley, and the latter left the company to establish a small laboratory of his own in a little alley in Yonkers. This modest workshop became the birthplace of some of the foremost electrical inventions.

Here Mr. Bradley devised the method of multipolar windings, now so generally used for direct-current machines. The first multipolar machine in this country was constructed by him in 1887. When the engineers of the Edison works in Schenectady tested it, it created a profound sensation. The first synchronous converter was built by Bradley in 1888.

We mention these inventions merely to indicate the broad scope of Mr. Bradley's genius; he is one of the very few men who are masters in many fields. What Mr. Bradley has done for electrochemistry will appear in the following analysis of his electrochemical patents.

Charles S. Bradley.

One of the first patents granted to Mr. Bradley (312,802, Feb. 24, 1885) was for a storage battery with zinc-bromide as electrolyte and zinc and carbon as electrodes. The carbon electrode, at which bromine is produced during charging, is at the bottom of the cell; the zinc electrode is at the top.

This cell has later independently been re-invented by Mr. H. H. Dow, who described it in a paper at the inaugural Philadelphia meeting of the American Electrochemical Society. The only difference between Bradley and Dow is that the former uses a porous diaphragm, while the latter finds this to be unnecessary. In the discussion of Mr. Dow's paper it was remarked that the cell is old, but its original invention was erroneously attributed to Prof. F. B. Crocker.

As this mistake has gone into the printed Transactions of the society, it may be corrected here. Mr. Bradley was the first inventor of this battery, while Dr. Crocker was then his patent attorney. It is impossible that this cell may still have a future, especially for the purpose for which Mr. Dow wanted to use it, namely, as a standard cell. It can be set up most easily, anywhere on very short notice.

The mechanical construction of the cell was later modified by Mr. Bradley. His patent (409,448, Feb. 24, 1885) is interesting on account of the remarkable clearness with which the theory of metallic diaphragms is correctly given in very few words—a subject which was only recently again under discussion.

While these two patents prove Mr. Bradley's early and thorough understanding of electrochemical problems, the class of his "internal heating" patents is of enormously greater industrial importance. Without entering into the legal questions, we may simply mention that his internal heating inventions have been and are the subject of extended legal battles, first between Mr. Bradley and the Cowles Co., and now between the Cowles Co. and the Pittsburg Reduction Co.

The application for three patents (464,933, granted Dec. 8, 1891; 468,148, Feb. 2, 1892; 473,866, April 26, 1892,) was filed on Feb. 23, 1883; relating to the use of the electric current for producing a combined heating and electrolytic effect, and to the application of this method to the production of aluminium.

For the use of electric current to produce a pure heating effect in order to avoid external heating of crucibles, a patent was granted to Messrs. S. S. Bradley and F. B. Crocker on Feb. 2, 1886, the application having been filed on March 14, 1885. In this case alternating currents are, of course, available, and may be even preferable.

An electric furnace in form of a revolving wheel, now well known in the calcium carbide industry, was patented by Mr. Bradley on Jan. 25, 1898 (No. 597,945). The very important effect of this arrangement is to make the process continuous. An improved form of this rotary, continuously working type of furnace, was recently patented by Mr. Bradley (patent 723,643, March 24, 1903).

In recent years Mr. Bradley's inventive activity has been closely connected with the work of the Ampere Electrochemical Co. at Niagara Falls, and its offshoot, the Atmospheric Products Co. Mr. Bradley is now president of the latter company.

The enormous amount of experimental work done by the Ampere Electrochemical Co. and the success of which has largely been due to the inspiration of Mr. Bradley is well known to our readers. Among the processes worked out by this company are a process of Bradley and Jacobs for fusing bauxite in an electric furnace and thereby producing a pure artificial corundum, as now operated by the Norton Emery Wheel Co.; a process of Bradley and Jacobs for working barium sulphate into barium hydroxide, as well as processes for making artificial camphor, cyanides, silicides, etc.

What may be considered, however, as the crowning success of Mr. Bradley's recent inventive activity is his and Lovejoy's process for the fixation of atmospheric nitrogen from the air. This process has been described repeatedly in detail in this journal, so that this scant reference must suffice here. The process is certainly one of the most splendid achievements in electrochemistry, and may be hoped to have far-reaching and radical industrial and agricultural results.

From this brief sketch of Mr. Bradley's activity it appears that his inventive genius is nearly unlimited. The inventor of multipolar winding and of the synchronous converter is at the same time a leading electrochemist, and in the field of electrochemistry he is an equally daring and successful pioneer along many lines. May Mr. Bradley, who is still in the best years of his life, continue his splendid activity for many years to come.

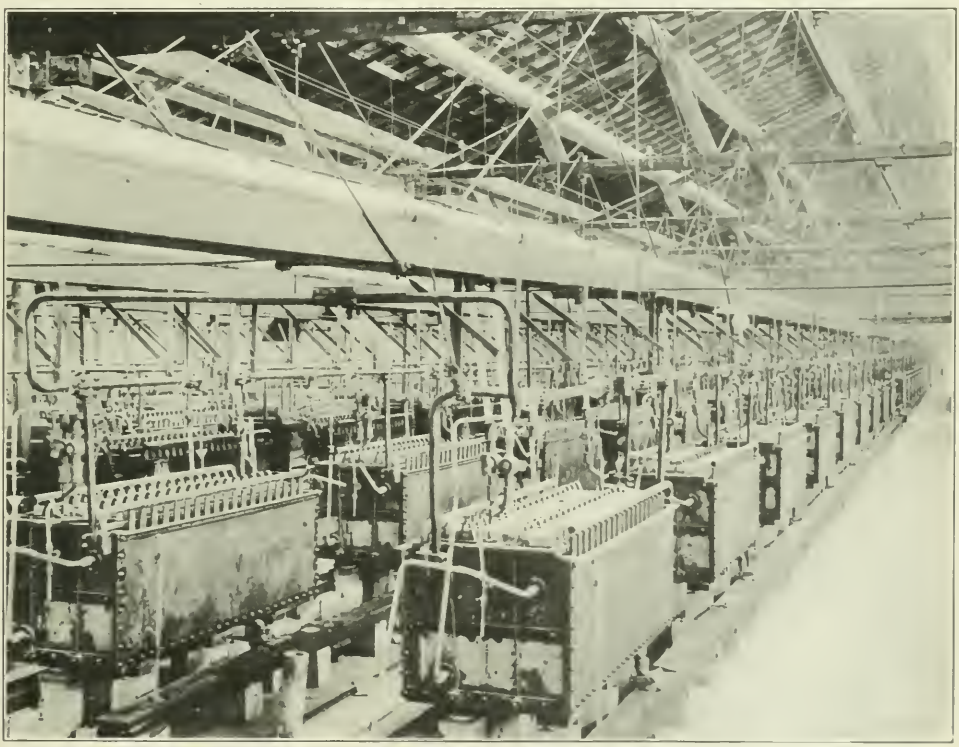
## PLANT FOR MAKING BLEACHING POWDER AND CAUSTIC SODA BY THE DIAPHRAGM PROCESS.

The technical problems involved in the production of caustic soda and chlorine by electrolysis of sodium chloride have been solved by a great many inventors in quite different ways. The only commercially successful process in which *fused* salt is electrolysed is the Acker process. In all other processes in actual operation *aqueous solutions* are electrolysed.

The principal problem is always to keep the anodic and cathodic products of electrolysis separate from each other, and this problem has been solved in three essentially different ways. The first is to separate both compartments mechanically by a diaphragm (diaphragm processes); the second is to keep the anodic and cathodic liquids separate from each other by making use of their different specific gravities (gravity process); the third is to eliminate the sodium ions discharged at the cathode from the cell by alloying them with the cathode (mercury cathode process).

The mercury cathode process has been made a commercial success by Castner and Kellner; it is in use at the works of the Castner Electrolytic Alkali Co. at Niagara Falls. The gravity process ("Glocken process") is the latest of the three general classes of processes, and has found practical application only in Germany and Austria to a comparatively restricted extent. Diaphragm processes have probably found the most extended use. Mr. E. A. Le Sueur performed early pioneer work for this process in this country, while abroad the diaphragm process was developed mainly by the Griesheim company in Germany. At present the Dow Chemical Co., at Midland, Mich., is the largest manufacturer in this country using the diaphragm process, while other diaphragm processes are in use in various pulp and paper mills in the United States, notably in the New England States.

A characteristic feature of the whole class of diaphragm processes is the great variety of the details of arrangements of the electrolytic cells used by different inventors. This is due to the fact that the introduction of a diaphragm does not solve the whole problem, because after electrolysis has gone on for a while, caustic soda has been formed in the cathode compartment and begins to participate in the conduction of the current so that hydroxyle anions travel over to the anode compartment and produce reactions which are not wanted



ELECTROLYTIC CELL ROOM FOR THE PRODUCTION OF CAUSTIC SODA AND CHLORINE. SOCIETA ITALIANA DI ELETTROCHIMICA.

This new problem is overcome by different inventors in different ways. We may note here, however, that this difficulty was clearly understood by Le Sueur in his early experiments; he counteracted this tendency of the OH ions by supplying fresh brine to the anode compartment and allowing bodily percolation through the diaphragm to occur under pressure.

In the following we give a description of an Italian plant in which a diaphragm process is used. As they are working under the Outhenin Chalandre patents, a brief description of this process, from United States patents 511,682, 647,217 and 665,953 may be here of interest.

As anode compartment a rectangular box is used; it is built of non-conducting plates, with rubber packing. A number of inclined porous tubes are arranged in vertical rows, and the vertical carbon anodes are placed between these rows of tubes. The cathodes are made in form of vertical sheet-iron combs, and the teeth of these combs extend into the porous tubes. A hood is provided for collecting hydrogen, cover-

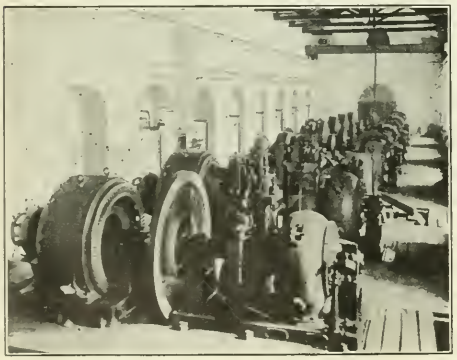
ing the higher ends of these tubes. Brine circulates between the anode compartment and a separate saturating vessel.

To counteract the tendency of the OH ions to do mischief in the anode compartment, Chalandre, Colas and Gerard utilize some of the hydrogen and chlorine which is developed in their electrolytic vats, to pass them into an outer chamber, where they are made to combine to form hydrochloric acid. This hydrochloric acid is supplied to the anode compartment to neutralize any caustic or decompose hypochlorite. The amount of hydrochloric acid used for this purpose is preferably 5 to 40 per cent of the amount of caustic produced in the same time.

PLANT OF THE SOCIETA ITALIANA DI ELETTROCHIMICA.

For the following information concerning the plant of the *Societa Italiana di Elettrochimica* and for the accompanying illustrations we are indebted to Sig. Cav. *Mario Michela*, in Rome. Fig. 1 gives an outside view of the plant, Fig. 2 shows the power plant, and Fig. 3 the electrolytic cell room.

The Societa Italiana di Elettrochimica has developed 6000



INTERIOR OF POWER HOUSE.

electrical hp. on the railway lines between Rome and the Adriatic Sea, and also has perpetual rights for 32,000 hp. more in the same place. The head of the waterfall is about 200 feet.

As mentioned before, the company works under the Outhenin Chalandre patents, using a diaphragm, which, after having been considerably simplified from its original construction, now is thoroughly satisfactory. They produce caustic soda of a high grade, viz., 75/77, and bleaching powder which is selling fairly well. However, the state of the market for the latter product is so unsettled that the company has decided to add a few more strings to their bow. They are now erecting supplementary plant for chlorates, pure synthetic hydrochloric acid, carbon tetrachloride, etc., from which they expect a better remuneration.

The Societa Italiana di Elettrochimica also has plants for sulphuric anhydride, under a license from the Badische Anilin und Soda Fabrik, and for other chemical products, which, however, are for the present out of the electrochemical field, but will, as they believe, be connected with it in the near future, after the development of more water-power.

## MEASURING ELECTRODE POTENTIAL

By Woolsey McA. Johnson.

In a preceding article (Electrochemical Industry, July, 1903, p. 373) I tried to give some conception of the electrochemical quantity "electrode potential," and tried to show that it was as definite a physical quantity as the pressure of steam in a boiler, or the pressure of water against the walls of a dam. The reason that one conception appears usually hazy and indefinite and the other clear-cut and well defined is that "pounds per square inch" is a perfectly familiar expression known in childhood, while "e. m. f. against the hydrogen electrode" is used only in a few recent text books on physical chemistry and is not usually known.

If the phenomena and terms were equally familiar, the conceptions would be equally easy for the mind to grasp. In my articles on this subject I will try to explain facts by known facts and the theory will be found to be useful, but not indispensable.

The gist of the article in the July number was as follows:

(1) Whenever an electrode dips into an electrolyte, there we find a seat of e. m. f. acting either with the current or against the current, according to the direction of the current in the circuit.

(2) Conversely, whenever a current passes from the anode to the anolyte, or from the catholyte to the cathode, then chemical change ensues and the energy necessary to affect this chemical change is equal to the "electrode potential" of the system, when one coulomb had passed through the system.

The present article will describe the various practical and laboratory methods for measuring this quantity, both when made artificially or electrolytically. When made artificially, we have simply to measure the e. m. f. of a "galvanic cell." When made electrolytically we measure the "decomposition voltage" (Zersetzungspunkt) or the "polarization voltage" of the electrolytic cell.

The old-fashioned practical way of measuring the e. m. f. of a galvanic cell is to put a voltmeter across the terminals. The old-fashioned practical way of measuring the decomposition voltage of an electrolytic cell was similar, to put a voltmeter across the circuit, read the volts, open the switch and read the volts on open circuit.

Both these methods are excellent, if one condition is fulfilled. This one condition is that the measuring instrument takes such a small amount of energy that the potential of the circuit is not diminished. For instance, if we started to measure the e. m. f. of a two-ampere-hour lead accumulator, with a six ohm voltmeter we would get a rapidly diminishing reading, while if we used a high-resistance Weston voltmeter we would get a very accurate constant reading. If we had a cylinder of ten gallons capacity, charged with compressed air at 100 pounds and attempted to measure this with a leaky pressure gauge, we would find that the leakage through the gauge would diminish the pressure, so that no accurate reading could be taken. If, however, the gauge was tight and well-made, and if the pressure diminished, we might reasonably infer that the cause was some outside leakage, not through the gauge.

In any case the reading is only an approximation to the truth, because all instruments measuring the potential of a system absorb a fraction of the total energy, and that fraction diminishes to some extent the potential of the system.

The voltmeter method is only a rough approximation, but it is valuable, because it is easy to carry out, and especially valuable if we know that it is an approximation.

The best conditions for the method are as follows: First, the system should be as reversible as possible; second, the voltmeter should have a very high resistance. Both of these are but special cases of the condition cited above.

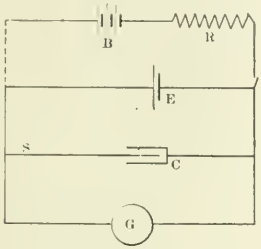



Fig. 1

CONDENSER METHOD.

If the system is very irreversible, or, to use the older term, polarizes quickly, we must use some instrument that absorbs only a modicum of energy. This is best done by availing ourselves of the static effects of electricity. An electro-static voltmeter, or the simpler form, the electrometer, can be used Perhaps, however, the best method is the so-called "condenser method" for measuring the e. m. f. of cells.

In Fig. 1 E is the cell whose e. m. f. we wish to measure. C is a condenser of about 1 or 2 microfarads capacity, S a two-way switch, and G a galvometer whose moving parts possess such inertia that the inertia takes all the "kick" on discharging C, and gives a reading functionally proportional to the quantity of electricity stored in C. Such a galvometer is called "a ballistic galvometer." For details of this instrument and method, the reader is referred to Carhart and Patterson's "Electrical Measurements."

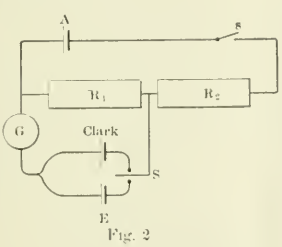



Fig. 2

POTENTIOMETER METHOD

The method briefly described is first to charge C to a known potential, using a Clark or a Weston cell. By afterward discharging the condenser charged to this potential through G, the constant of the galvometer is found. The same procedure is followed substituting the unknown e. m. f. for the standard cell.

If the unknown e. m. f. is 1 volt, and the capacity of the condenser 1 microfarad, only 0.000001 coulomb of electric "juice" has been absorbed from the system. Such a small quantity can diminish its potential but slightly.

But, unfortunately, the electrode potential can drop of its own accord, just as the pressure of the air in the cylinder referred to above can decrease, not only through a leaky gauge, but through leaks in the cylinder itself.

To render this measurement more reliable, we must use some device that will charge the condenser at a definite period after breaking the main circuit (shown in Fig. 1, by B, the polarizing battery, and R, a resistance in series with it). Such a device is the Helmholtz pendulum, worked out by von Helmholtz several decades ago, with simple mechanical features. The period between break and make can be changed by one-millionth of a second steps. Such a method, with this refinement, is particularly desirable in measuring the electrode potential of a system in unstable equilibrium like the persulfation at the end of the charge at the anode in a lead accumulator. By varying the interval of time we can plot the curve of "auto-depolarization." This method can be recommended as the most accurate and scientific for measuring a rapidly changing electrode potential.

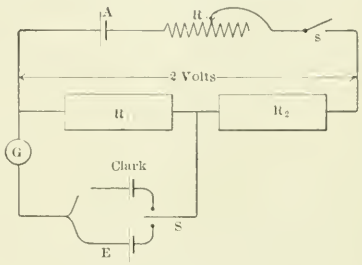



Fig. 3

POTENTIOMETER METHOD.

When the electrode potential does not vary by "auto-polarization" the "potentiometer" method is undoubtedly the most accurate method. In its simplest form, it is simply a known e. m. f. closed through a resistance box with a variable shunt circuit containing a galvanometer and the unknown e. m. f. connected so as to oppose the flow of current of the known e. m. f. By varying the resistances so that no current flows through the galvometer, we have the drop in voltage across that part of resistance in multiple with the shunt circuit exactly equal to the unknown e. m. f. It goes without saying that the known e. m. f. should be larger than the unknown e. m. f.

In a slightly more complicated form it is shown in Fig. 2. An accumulator A is placed in circuit with two 10,000 ohm resistance boxes $R_1$ and $R_2$. Around $R_1$ is a shunt circuit consisting of a sensitive galvonometer G and in series with either a Clark cell or the unknown e. m. f. E. The two-way switch S allows putting in the circuit at will, either the Clark or E.

The procedure is to close *s*, and throw in the Clark by S.

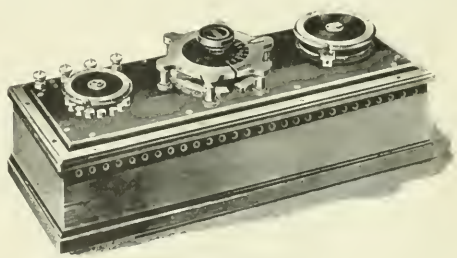


FIG. 4—DIRECT READING POTENTIOMETER.

then to vary $R_1$ and $R_2$, so that their sum is exactly 10,000 ohms, and that $R_1$ is of such a value that no current flows through G whose needle must then point to zero. Then, if the e. m. f. of the Clark standard cell be taken as 1.433 volts at 15° C., the e. m. f. of A is found thus:

$$\frac{\text{e. m. f. of A}}{\text{e. m. f. of Clark}} = \frac{R_1 + R_2}{R_1}$$

for as the system is in equilibrium the voltages are proportional to their resistances. Then we have voltage of A $= 1.433 \frac{10{,}000}{R_1}$, because $R_1 + R_2 = 10{,}000$ ohms, and the e. m. f. of the Clark cell = 1.433 volts.

If the temperature of the Clark cell be not 15° C., but t° C., the true e. m. f. can be found by the formula $E_t = 1.433 - 0.012\ (t-15)$ volts.

If, instead of the Clark cell, the Weston cell be taken, its e. m. f. is $E_t = 1.0186 - 0.00004\ (t-20)$ volts.

The temperature-coefficient of the e. m. f. of the Weston cadmium cell is so small that a change of 25° C. makes only a difference of a millivolt. Accordingly for all ordinary work, the e. m. f. of the Weston cell can be taken as 1.019 volts at room temperature.

Having found the e. m. f. of A, the secondary or working standard, S is now thrown so as to put E in the circuit. If

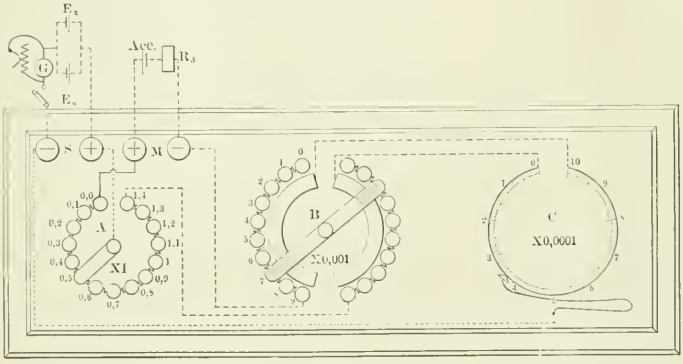



Fig. 5

CONNECTIONS IN DIRECT-READING POTENTIOMETER.

the e. m. f. of E is known roughly, it is easy to make $R_1$ about the right value. This will naturally save considerable manipulation of the plugs. One set of plugs should be removed and put away. Then, whenever one plug is removed from one resistance box it should be placed in the corresponding hole in the other. Thus the sum of $R_1$ and $R_2$ is kept at 10,000 ohms without much mental labor. Now we have, if we make the new value $R_1'$ so that the galvanometer needle is again at zero, $\frac{\text{voltage of E}}{\text{voltage of A}} = \frac{R_1'}{10{,}000}$, hence the e. m. f. E in volts is $E = \frac{1.433}{R_1} R_1'$.

From this relation it is seen that if $R_1$ were divisible by 1.433 an even number of times, as 1000, we should get the value of E from the resistance $R_1'$ by the simple operation of pointing off.

It is quite easy to make $R_1$ divisible by 1.433 an even number of times by putting in series with A a resistance. If this resistance is so chosen that the drop through $R_1$ and $R_2$ is 2 volts, then 5 ohms in $R_1$ will correspond to one millivolt. A simple arithmetical calculation will show this to be the case, if in the comparison of A with the Clark cell the value $R_1$ were made 7.165 ohms, and the third resistance $R_3$, seen in Fig. 3, adjusted so that G showed no deflection.

Such an apparatus can be set up out of ordinary resistance boxes, and will do excellent work. But by far the best is to have them combined in one instrument so that all the parts fit each other. I have considerable experience with several of these so-called "direct-reading potentiometers." The simplest and cheapest was made for me by Dr. R. Franke, of Hanover, Germany, and is shown in Fig. 4.

Its greatest drawback is the fact that its total resistance is only some 1500 ohms. Now, most accumulators will polarize to some extent in the millivolts in five minutes, if closed through 1500 ohms. This objection to the method I overcame by making a Plante cell of large electrode surface with a large amount of electrolyte, and with the lead only formed very slightly. Now, if the electrolyte in pores of the electrode becomes dilute by sulfation of electrolytic action, it will be easily replaced by the large amount of acid that will diffuse readily through the *thin* layer of active material. As the e. m. f. of a lead accumulator depends on the strength of acid in the active material, if that acid be kept constant, the e. m. f. will be constant.

Fig. 5 shows the scheme of connections in the Franke direct-reading potentiometer.

The first resistance A consists of 1400 ohms with taps coming at intervals of 100 ohms to a circular series of German silver contact knobs. A contact brush revolving over the tops of these knobs allows any step from 0 to 1400 ohms in 100 ohm intervals.

B is a second resistance of 180 ohms, arranged similarly in 10-ohm steps, but with a double-contact brush, so that only 90 ohms is in the main circuit, and any resistance in the series 0, 10, 20, 90 ohms in the shunt circuit. C is a circular revolving resistance of even calibre with a slide contact. The resistance C is always in the main circuit, which thus is ever equal to 1500 ohms. The part of C in shunt circuit is read on the scale of this circular bridge wire. The mechanical arrangement can best be seen by glancing at cut, Fig. 4

Acc is the special lead accumulator, $R_3$ is the adjustable outside resistance of such a value that 1.500 volt is the drop through A B C. Thus the drop through one ohm is exactly one millivolt or 0.001 volt. Ew is the Weston standard cell, and Ex the cell whose e. m. f. we wish to measure.

The method is nearly the same as in the preceding method. As a Weston cell is used whose e. m. f. is 1.019 volts, we put

| | |
|---|---|
| A at | 1,000 ohms |
| B at | 10 ohms |
| C at | 9 ohms |
| total $R_1$ = | 1,019 ohms, corresponding to 1.019 volts. |

$R_2$ is then adjusted until G gives no deflection.

The galvanometer had best be connected with a small variable shunt resistance. At first the shunt resistance is made small so that only a small fraction of the current flows through the galvanometer. Thus only a fair deflection of G's needle is made. As the adjustment on the potentiometer becomes finer, this resistance is increased and finally, when the balance is nearly reached, the shunt can be cut out and the galvanometer is used in its most sensitive condition. If no shunt were used, the galvanometer might be seriously injured by using it with too high a voltage.

Another method might be used to change the sensitiveness of the galvanometer. I have never used this method in electrolytic work, but have found it very useful in other work. This is to have the field of a d'Arsonal galvanometer not set up by a permanent magnet, but by an electromagnet. By having a variable resistance in series with this electromagnet, the

strength of the field can be varied by varying this resistance.

Having adjusted the instrument so that exactly 1.500 volts is delivered at the terminals, Ex can be thrown in and measured by moving the revolving contacts until the galvanometer shows no deflection.

The only "contact resistances" that vary the *resistance of the main circuit* are the two of B. These contacts are accordingly made large, as can be seen in Fig. 4. The resistance of contact should never be higher than 0.01 ohm, which would mean 0.0001 volt—of course a quantity too infinitesimal to be measured. The other resistances are in outside shunt circuit, and even if they were large, could only have the effect of diminishing the sensitiveness of the galvanometer.

If we know the approximate value of Ex we can set A and B at right shunt values, and often do all the adjustment on C. In any case we can read the e. m. f. in volts directly from the positions of the revolving contacts of A, B and C. Hence the name direct-reading potentiometer.

The preceding methods enable one to measure the e. m. f. of an electrochemical system, or, in other words, to measure the difference of "electrode potential of two electrodes." Both these methods usually measure the e. m. f. of the cell when the cell is inactive, and no current is passing through it. The cell can be made either chemically or electrochemically. The following method measures the electrode potential of a cell as a result of electrolysis, by measuring the amperes as a function of the impressed volts. Simply a voltmeter is placed across the cell and an ammeter in series with cell. The method is to determine the "characteristic" curve of the cell.

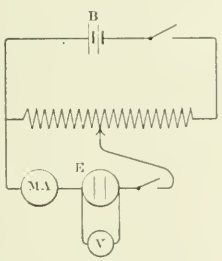



Fig. 6

MEASURING DECOMPOSITION VOLTAGE.

The usual term is measuring the "decomposition voltage" (Zersetzungsspannung). In Fig. 6 we see the diagrammatic sketch of the apparatus.

B is a battery of two lead accumulators, with a switch, and R is a resistance (with shunt) of about 200 ohms. (M A) is a milliammeter of low internal resistance. E is the cell whose decomposition voltage we wish to measure. (V) is a *high resistance* voltmeter reading to 3 volts. For both M A and V proper galvanometers can be substituted, but Weston instruments are by all odds the best. R can well be a cylindrical Kohlrausch bridge, and its reading will give that part of the 4 volts applied to the shunt circuit.

To take a concrete example we will now consider that we are measuring the decomposition-voltage of the halogen acids—HCl, HBr and HI. The cell can well be a small breaker of 200-cc capacity, through whose wooden cover are led two platinum wires sealed in glass. These wires should be about one-half an inch apart.

It must be remembered that we are creating two new electrodes and measuring the difference of electrode potential of these two new electrodes. In the case of HCl, hydrochloric acid, we measure the difference of potential between electrolytically formed hydrogen in platinum and electrolytically formed chlorine, also in platinum.

Should we wish to measure the potential of one new electrode, we can have recourse to two methods; we can either make the electrode whose potential we wish to measure very small in comparison to the other; this will remain constant and we measure the change in other; or we may put in cell a third auxiliary electrode and measure the voltage of each against this.

The test cell is now filled with normal hydrochloric acid. We next impress upon E a voltage of 0.05 volt, as seen on the bridge reading, wait ten seconds and read both V and MA. The impressed voltage is increased by steps of 0.05 volt, and in each case after 10 seconds the voltage and amperage are read. At first, there is seen a very small deflection of the ammeter, which does not increase until 1.30 volts have been reached. Here the pointer of the ammeter begins to show signs of life. We now increase the voltage by steps of 0.01 volt, and soon the ammeter begins to increase rapidly. When 1.45 volts are reached the test has been completed. On plotting the readings it will be found that the curve is in a boomerang shape. One limb of the boomerang is near the X-axis. At about 1.30 volts the curve seems to take a bend (more or less sharp), and the other limb of the boomerang is seen mounting nearly vertical. By drawing a tangent to both limbs it will be found that the tangents intersect each other at 1.31 volts. This value 1.31 volts is the so-called "decomposition voltage" of hydrochloric acid, and is a measure of the electrical energy necessary to break up hydrogen chloride. It is also a measure of the force with which the hydrogen ion and the chlorine ion are bound to each other by the means of the solvent water.

The dynamical relation between anion, cation and solvent is unknown, but in the nature of things it is some form of a closed polyhedron. When the strain on any member of the figure exceeds the force, binding the figure together, we have disruption. It is quite a pretty coincidence that the curve of "decomposition voltage" of hydrochloric acid resembles th curve made in finding the "elastic limit" of steel for example. In each case, when the force exerted on the system from the outside is large enough to overcome the cohesive force of members of the system, "something has to go" and it does go. In each case the point is not sharp and varies with the method.

We will now replace hydrochloric acid with hydrobromic acid, and the decomposition voltage is found at 0.94 volt. When hydroiodic acid is used the "voltage" is found to be 0.52 volt. In each case we can see the visible electrolysis at the same time the ammeter reading begins to increase. When 0.53 volt is rached with HI heavy brown clouds of iodine can be noticed descending from the anode.

Now, if we use HCl solutions of different concentrations the "decomposition voltage" will be found to vary. LeBlanc gives these values:

| | |
|---|---|
| 2n HCl | 1.26 volts. |
| n HCl | 1.31 volts. |
| .2n HCl | 1.34 volts. |
| 1-6n HCl | 1.41 volts. |
| 1-16n HCl | 1.62 volts |
| 1-32n HCl | 1.69 volts. |

With 1-32 HCl we have reached a point where no longer Cl is given off but a large proportion of oxygen

Naturally in the electrolysis of brine, or of $ZnCl_2$ or $NiCl_2$, with the production of chlorine at the anode, the curve of electrolysis should be studied. The results should be expressed, not in "amperes per square foot," but in electrode potentials.

If the brine contained with NaCl a proportion of NaBr and NaI, it would he perfectly possible to partially separate these electrolytically from the NaCl and from each other, just as it is possible to partially separate copper from nickel electrolytically at the cathode or in the case of a soluble metallic anode, silver from copper, gold from silver or platinum from nickel by "sliming" the less electropositive metal

In almost all cases the separation is not complete, but only a concentration product is formed.

So the concentration product containing Br and I could be subjected to a second electrolytic action and a higher concentration product obtained. Finally the treatment could be carried on chemically with cheap brine, and cheap power; there would be a wide margin of cost when the high-selling price of Br and I are considered.

The above is mentioned merely to show how important it is when attacking any practical proposition to know fundamental scientific facts. In a further article I will discuss the various standard electrodes, and treat of electrode potential from the standpoint of thermodynamics and the dissociation theory.

## THE ST. LOUIS WORLD'S FAIR AND ELECTROCHEMISTRY.

Since the 1902 convention of the American Electrochemical Society at Niagara Falls, at which time a participation in the Universal Exposition in 1904 was first discussed in the Society, developments have been rapid and convincing on the World's Fair grounds in St. Louis.

To those who have not been fortunate enough to visit the exposition grounds within the last two months, the illustrated journals give at best but a poor idea of what the exposition is and is to be. To use the words of Commissioner General Lagrave, of the French Republic, to the Louisiana Purchase Exposition, "The site is ideal in the extreme." All of the sixteen great exposition buildings will be completed by the first of October, and seven of them are completely finished to-day.

It is well worth the while of any one who may find himself within easy reach of St. Louis to visit the grounds, and see for himself the great scale of progress made upon the exposition.

### The Electrochemical Exhibits.

It is gratifying to know that the present space requirements of the electrochemical exhibits exceed 10 per cent of the exhibit area of the palace of electricity. The present prospects have far outrun the hopes which were entertained last year.

Among the exhibitors are the pioneers in electrochemistry, and some of the most vigorous representatives of the Niagara Falls electrochemical colony.

Whole processes will be shown, and the display in its entirety will be well worth the study and consideration of the electrochemist, and deserving of inspection, even to the limitation, should time demand, of the other elements of the exposition.

There will also be a number of important electrochemical exhibits shown in the building devoted to mines and metallurgy. Close co-operation between the chiefs of this department and the electrical department is insuring the success of the details of the various exhibit schemes which are being carried into effect. These departments are also organizing a plan for a demonstration, at the time of the International Electrical Congress, of special features, in a temporary building to be placed on the hill back of the Palace of Mines and Metallurgy, this site being available as well as readily accessible.

### Exhibit of the American Electrochemical Society.

We wish to urge upon the membership of the Society the necessity of responding promptly to the request recently sent out by Secretary Reed on behalf of the Society's committee for an historical electrochemical exhibit. Such an exhibit will greatly redound to the credit and advantage of the Society, which ought to be represented in an appropriate and dignified way by an exhibit commemorative of the development of electrochemistry in conjunction with similar exhibits which are being prepared by presentation by the American Institute of Electrical Engineers, the British Institution of Electrical Engineers, besides four of our other national American engineering societies. President Richards is the chairman of the Society's committee having charge of the preparation of the exhibit, and all persons who can contribute or know of important electrochemical apparatus should communicate with him as soon as possible.

### The International Electrical Congress and the American Electrochemical Society.

The International Electrical Congress has now reached such definite proportions that its success is entirely assured. The fact that it is organized with Prof. Elihu Thomson as president, Mr. B. J. Arnold as vice-president and chairman of the executive committee, and Dr. A. E. Kennelly, of Harvard, as secretary, assures that it will demand recognition abroad as well as at home.

The congress will consist of two important divisions: First, a chamber of official delegates made up of representatives of the great world powers, upon invitation of the United States Government, to take up for discussion all matters that are of international importance and affecting the electrical industry; second, the general electrical congress participated in by the members of the European and American electrical associations. The general congress will be divided into a number of sections, and these sections, through co-operation of our national electrical bodies, will be organized with the full support of the branches of the science which they cover.

The annual conventions of all of our prominent national electrical organizations will be held in St. Louis in conjunction with the congress, and will hold joint sessions with appropriate sections of the congress. This naturally will place the American Electrochemical Society in the position of being sponsor for the electrochemical section of the congress, and will present a most gratifying opportunity for bringing the Society into the closest and most harmonious touch with all the prominent electrochemical movements of the world.

The time seems ripe and the opportunity at hand for the bringing about of the concourse of electricians such as the world has not before seen. We congratulate the Committee of Organization of the International Electrical Congress of 1904 on the plan and scope of the scheme which it has developed, and we congratulate the Electrochemical Society upon having joined so heartily in supporting all the movements.

## INTERNATIONAL CONGRESS FOR APPLIED CHEMISTRY.

Report of the Proceedings of Section X.

(Electrochemistry and Physical Chemistry.)

By H. Danneel, Ph. D., and J. K. Clement.

### First Meeting (June 3).

The section was welcomed by the president, Dr. Boettinger, of Elberfeld. The first paper was presented by Traube entitled:

### An Investigation of Critical Density.

The author formulated a theory that the gaseous and fluid molecules of a substance are quite distinct from one another, and that especially their individual volumes, which are represented in Van der Waals' formula by $b$, are very different. A fluid, according to this theory, is a solution of gas molecules or "gasons" in "fluidons," whereas a gas is a solution of the latter in the former. The solubility of the one in the other increases with rise of temperature, and the solubility curves meet at the critical point.

The experimental proofs which the author gave in support of his theory are chiefly as follows. Glass bulbs of different known density were enclosed in a tube filled with pure carbon tetrachloride, and this was heated in a thermostat to a point above the critical temperature. It was observed that at 10° above the critical temperature the bulbs remained still floating for hours at different heights. At a point several degrees above the critical temperature, differences in density of 50 per cent and more were shown.

In the discussion which followed, and in which Teichner, Kistiakowsky and Traube participated, Tammann pointed out

that the presence of small quantities of impurities would account for these phenomena.

### THE DETERMINATION OF MOLECULAR WEIGHTS AT HIGH TEMPERATURES.

This paper, presented by W. NERNST, dealt essentially with the same subject as his paper presented at the New York meeting of the American Electrochemical Society (ELECTROCHEMICAL INDUSTRY, May, p. 319; Transactions of the American Electrochemical Society, vol. III., p. 75). Some additional results were, however, given which Nernst has obtained in the meantime. Sulphur, at the high temperature of the experiments, is appreciably dissociated, at least 45 per cent of S being dissociated at a temperature between 1900° and 2000°. It is possible that at high temperatures the three-molecule $S_3$ may be formed in a manner analogous to the formation of ozone ($O_3$). Sulphur dioxide was found to be stable up to 1950°. At such temperatures silver has vapor pressure considerably below atmospheric pressure.

### A NEW ELECTRICALLY HEATED RESISTANCE FURNACE.

The furnace described by O. FROEHLICH is made of stoneware, the conductivity of which, at ordinary temperature, is sufficiently large to permit the flow of the current necessary to warm it. With rise of temperature the conductivity increases and the furnace is said to bear a temperature of 1600°. The material of the furnace has also the property of retaining the heat to a marked degree. No important particulars regarding the furnace were given as a patent has been applied for.

In the discussion Drossbach remarked it is wrong to believe that up to the present a material is not known which does not conduct when heated. Pure oxides are practically non-conductors, and conduct only when impurities are present. Nernst confirmed that under 1800° oxides are non-conductors; thorium and magnesium oxides only conduct when mixed. There are in fact only a few oxides that have not been experimented upon in this direction (see Reynolds, *Jahrbuch der Electrochemie*, vol. 7, p. 151, 1900).

## SECOND MEETING (JUNE 4).

### COLLOIDAL ZIRCONIUM.

A paper on this subject was presented by E. WEDEKIND. When zirconium earth ($ZrO_2$) is reduced by smelting with aluminium a product is obtained, which, on treatment with water, gives a blue fluid containing colloidal zirconium. The zirconium in solution is not precipitated by electrolytes, but by $H_2O_2$ (hydrogen peroxide), the latter not being destroyed by the colloid.

In the discussion Whitney remarked that colloidal zirconium has the property, which other metallic colloids are known to possess, in that under the influence of an electromotive force it migrates in the direction opposite to the current

### METALLIC CARBIDES

In a paper on this subject H. MOISSAN, of Paris, whose work on inorganic syntheses in the electrical furnace is so well known, gave a resumé of his experiments with metallic carbides. The various particulars which he gave have already appeared in the "*Comptes Rendes de l'Academie des Sciences*." There was no discussion.

### ELECTROLYTIC REDUCTION OF UNSATURATED COMPOUNDS

A paper on this subject was presented by C. MARIE. The addition of hydrogen to unsaturated hydrocarbons can easily be performed by means of electrolysis when the proper cathode is chosen. With mercury as cathode it is possible to convert unsaturated acids, such as fumaric, cinnamic, aconitic into the corresponding saturated acids.

In order to avoid oxidation at the anode, the author makes use of the following apparatus. A layer of mercury is brought into a wide vessel, the bottom of which is formed by a diaphragm, and upon the mercury is brought the solution to be reduced. The vessel is placed in a solution of caustic soda, and is connected with a battery, the negative pole with the mercury, and the positive with an electrode immersed in the solution of alkali. Under these conditions amalgam is continuously formed which acts as the reducing agent.

In the discussion Elbs remarked concerning cinnamic acid that this acid is oxidized with difficulty into benzaldehyde and carbon dioxide, but is easily reduced to phenylacetic acid. The difference between both process is so great that if no diaphragm is used, very little benzaldehyde is formed, while the yield of phenylacetic acid is almost quantitative.

### THE IMPORTANCE OF ELECTROLYSIS FOR THE PREPARATION OF INORGANIC COMPOUNDS.

A paper on this subject, presented by F. FOERSTER, was an account of the uses of electrolysis for the manufacture of inorganic substances, and of our present knowledge concerning the mechanism of electrochemical action at the electrodes. It is not possible to give an abstract of this condensed report without translating it almost word for word. Attention, however, might be called to the fact that ceric sulphate ($Ce(SO_4)_2$), as an oxidizing agent, stands very near to permaganic acid relative to its oxidation potential. The ceric sulphate can be regenerated by means of electrolysis, from the cerous sulphate $Ce_2(SO_4)_3$ formed. This material appears to have a great future on account of its strong oxidation properties, and the ease with which it can be regenerated. Bright platinum foil in a solution which contains 0.1 grammolecule of Ce $(SO_4)_2$, and 0.05 grammolecule of $Ce_2(SO_4)_3$, and which is normal relative to $H_2SO_4$, has a potential of —1.45 volts against the hydrogen electrode.

In the discussion Loeb inquired how Foerster would explain the fact that copper anodes in a chloride solution give monovalent cuprous ions, whereas in a neutral solution of copper sulphate bivalent cupric ions are formed. Foerster in reply said he believed that at first always monovalent ions are formed, and that these are much more stable in the chloride solution than in nitrate, on account of the formation of complex ions in the former.

Wohlwill agreed with Foerster that at first the simplest ions are formed, but that they only remain when they are stable in the respective solutions. For example cuprous ions are unstable in nitrates and sulphates, and are immediately transformed into metallic copper and cupric ions. In other cases phenomena take place, which are not yet explained. For instance, we do not know why Sn in $H_2SO_4$ always goes into solution as bivalent ion. Whereas in other solutions the tetravalent ion is formed.

Pure gold is dissolved usually as univalent ion in chloride solutions, but if alloyed with platinum, it forms trivalent ions.

### THE IMPORTANCE OF ELECTROLYSIS FOR THE PREPARATION OF INORGANIC COMPOUNDS.

This communication, by BRANDEIS, was a condensed account of the application of electrolysis to the manufacture of inorganic chemical compounds, and does not lend itself to a further abstract

### ELECTROLYSIS BY MEANS OF ALTERNATING CURRENTS

A paper presented by LEBLANC gave an account of an investigation of the assumptions made in Richards' and Roepper's patent on this subject. It is maintained by the inventors that by electrolysis of a hyposulphite solution between cadmium electrodes by means of alternating currents, a good yield of cadmium sulphide is obtained. By the impact of the current in one direction on the electrode cadmium sulphide is said to be formed, while by the next impact of the current in the opposite direction hydrogen is formed which forces the CdS from the electrode and causes it to drop to the bottom

LeBlanc and Schick found, however, that a current of 1000 alternations per minute (i. e., a frequency of about 8 periods per second), and a current density of 4.6 amperes per square centimeter gave practically no yield. A smaller frequency gave

ter results, and an efficiency of 75 per cent was obtained with one alternation per minute, the solution at the same time being well stirred.

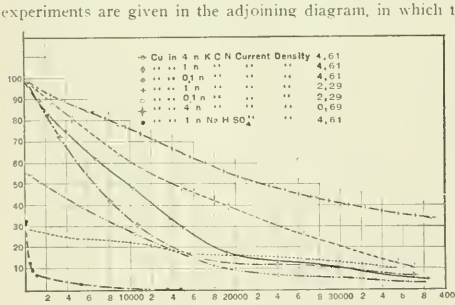
With direct current and abundant surring a theoretical yield of CdS was obtained. From these results it appears that the CdS which had been formed anodically, undergoes cathodic reduction, and that the yield obtained with low frequencies is due to the fact that the sulphide is removed from the electrode by stirring and cannot be reduced.

Researches of this kind enable us to form some idea of the rate of reaction in inorganic solutions, a subject on which very little is known. If a copper electrode is electrolyzed in KCn solution two cases are possible. First, if the alternating current has a very low frequency, the copper, while anode, goes into solution by the impact of the current, and dissolves in the KCn. When the direction of the current is then reversed, copper is not deposited back, for out of a solution of KCn containing Cu the H is given before the Cu, this being due to the formation of a complex compound which makes the concentration of the copper ions very small. The second case is that the impacts of the current follow one another so quickly that the copper has no time to combine with the CN ions, and by the next impact of the current the copper is redeposited.

In the first case the copper electrode is dissolved according to Faraday's law, and in the second the copper electrode behaves like a platinum one and remains as it was.

If the number of alternations be varied and the two numbers found for which the copper is dissolved according to Faraday's law, and for which it remains unaltered, then the velocity of the reaction between Cu and CN must lie between the two half-periods which correspond to the numbers of alternations.

In each experiment the frequencey was varied between 1 and 4000 alternations per minute. The results of one series of experiments are given in the adjoining diagram, in which the




ELECTROLYSIS WITH ALTERNATING CURRENTS.

current efficiency is given in per cents as function of the number of alternations per minute. The diagram also shows the influence of a change of concentration, and of a change of current density.

The velocity with which the copper ions react is very great, but is nevertheless capable of comprehension. When copper ions in a solution of 0.1 normal concentration are brought together with a potassium cyanide solution of .4 to 1 normal concentration the reaction is nearly completed within a thousandth part of a minute. By means of exterpolation the author estimates that with 80,000 alternations per minutes, and a current density of 4.0 amperes per square decimeter in a 4 normal KCN solution, no copper remains in solution.

If copper ions in 1-800 normal concentration come together with 4 to 1 normal potassium cyanide solution the author estimates that after 1-80,000 part of a minute the reaction had hardly begun. From these two limit numbers we obtain an idea of the velocity with which the reaction takes place.

In the discussion which followed Krueger remarked that the polarization capacity of a mercury electrode, in KI or KCN solutions, along with the corresponding mercury salts, varies in a manner different from that which would follow from Warburg's theory in which diffusion is assumed to play the chief part. It is possible that the velocity of reaction is the controlling factor.

Wohlwill inquired if diffusion did not play an important part in LeBlanc's experiments. To this LeBlanc replied that experiments made with copper electrodes in solutions where no complex ions were formed show that for a frequency of from 1 to 2000 per minute practically no dissolving of copper is observed, and that the influence of diffusion has therefore already disappeared.

Nernst believes that by the method indicated by Krueger it is possible to arrive at a perfect theory. He pointed out that LeBlanc makes the silent supposition that the velocity of the dissociation of a water molecule into hydrogen and hydroxyl ions is infinitely great, compared with the velocity of dissociation of the complex ions into Cu and CN ions. LeBlanc agreed that this supposition is made, but gave the grounds upon which it is based.

### Remarks on the Electrometallurgy of Aluminium.

G. Gin, of Paris, spoke of the physical and chemical conditions necessary for electrolytes used in the industrial preparation of aluminium. His communication, however, comes rather "post festum," for these conditions have for some time been well known. The electrolytes must possess a low melting point, must be very fluid when melted, must have a lower specific gravity than aluminium, and low-vapor tension and minimum electrolytic resistance. Chemically the electrolyte must belong to the least exothermic compounds. The energy required for the preparation of aluminium depends upon the resistance of the electrolyte, and upon the electromotive force of polarization. The calculation of the amount of this e. m. f. from the heat of reaction gave for $Al_2F_6$ 2.49 volts, $Al_2O_3$ 2.19 volts, $Al_2S_3$ 1.27 volts. The calculation, however, is incorrect, because the e. m. f. should be found from the Gibbs-Helmholtz equation, and not from Thomson's rule. The author finds that the difference in the consumption of energy by the various proposed electrolytes hardly amounts to a cent per kilogram of aluminium. In consequence, the cost of making aluminium depends far less upon a low e. m. f. of decomposition than upon the market price of the electrolyte. The question of cost is thus more of a chemical than of an electrochemical nature. By electrolysis of a mixture of cryolite and aluminium sulphide Gin obtained aluminium sulphide in bright red crystals.

### Chemical Reactions at High Temperatures and Their Industrial Application.

A paper on this subject was presented by Zenghelis, of Athens. By burning aluminium powder in a stream of oxygen in a Hessian crucible, it was sought to obtain by chemical means a temperature equal to that of the arc light. The author estimates the temperature which he reached to be at least 4000° C. The aluminium oxide melted and partly volatilized, condensation taking place on the cold parts of the crucible. Platinum foil also volatilized. Oxide of lime and oxide of magnesium melted and partly volatilized, the remainder combining with the oxide of aluminium to form an aluminate. The excess of aluminium oxide melted to small balls, which were very hard (7½ to 8 hardness). The excess of oxygen was transformed into ozone. Presence of nitrogen and carbon gave aluminium nitride and carbide respectively. The gases $H_2O$, CO, $CO_2$, $N_2O$ were reduced by the aluminium. NO gave nitride and oxide.

There was no discussion, but it might be here remarked that the temperature of 4000° which Zenghelis has given, but not measured, is too highly estimated. $Al_2O_3$ volatilizes partly in the Heraeus furnace. Platinum volatilizes when it is used to fasten the Nernst incandescent filaments; CaO always by the

preparation of carbides. The formation of the nitride also takes place at a temperature much lower than 4000°.

THE MANUFACTURE OF IRON AND STEEL IN THE ELECTRIC FURNACE.*

A paper on this subject was presented by H. GOLDSCHMIDT. He gave in a table a list of the principal electric furnace methods for the production of iron and steel, with the names of the inventors, types of furnaces, and other data. The year given is the year in which the first description was published or the patent granted.

For the German patent office Goldschmidt has recently made a test of the Stassano method and this has shown that Stassano has succeeded in preparing workably ductile kinds of iron directly from ores, with less than 0.2 per cent of C.

Stassano makes use of the very pure iron ores found in northern Italy, and which have not yet been much used. The low price of water-power in that neighborhood is also in his favor.

Comparing the efficiency of coal in metallurgical processes with electricity used for the same purpose it is seen that electricity can only successfully compete when the price of the former is high.

The heating of the charge in Stassano's furnace is performed entirely by the radiation from a powerful arc (see ELECTROCHEMICAL INDUSTRY, 1903, p. 249, Fig. 1). This is operated at about 170 volts, with an alternating current of 2000 amperes. The length of the arc, after the furnace has been some time in operation and has attained a constant temperature is about 1 meter (3.3 feet); it operates with a loud crackling sound. The careful manner in which Stassano arranges his charges in order to get perfect reduction and a high yield is shown in a table giving the composition.*

Stassano uses mainly ores, but sometimes also waste sheet steel and raw iron. The charges are, therefore, of a mixed nature. The energy required for the reduction from ores is, of course, much greater than for melting iron for the production of steel.

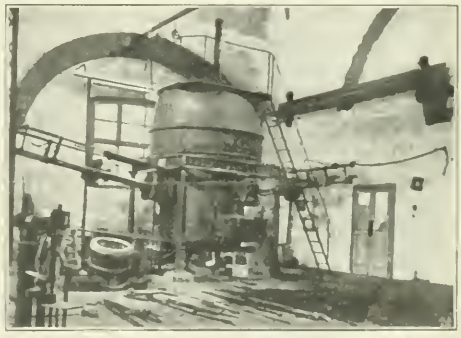
To get steel of the quality of crucible steel by means of the Stassano process, further improvements are necessary which, however, appear quite possible.

Goldschmidt then gives some figures for the Conley process and discusses at greater length the process of Keller** and Heroult.***

Keller's calculations are nearly similar to those of Stassano,

COMPARISON OF ELECTRIC FURNACE METHODS FOR PREPARATION OF STEEL BY THE ELECTRICAL METHOD.

| METHOD OF | YEAR. | TYPE OF FURNACE. | MATERIAL USED. | ENERGY IN H. P. HOURS PER TON OF STEEL. | COST IN DOLLARS PER TON OF STEEL. |
|---|---|---|---|---|---|
| Gin-Leleux | 1897 | Furnace with carbon electrodes. | Cast iron and waste sheet iron. | ..... | ..... |
| Stassano * * | 1898 | Furnace with carbon electrodes, 500 H. P. | High per cent. Italian iron ore. | 3800–4000 | 18.75 |
| Gysinge * * * (Crucible steel quality) | 1900 | Furnace without carbon electrodes, 225 H. P. | Cast and wrought iron. | 1320 | 43.00 |
| Froges–Heroult † | 1901 | Furnace with carbon electrodes, 400 H. P. | Cast iron and waste sheet iron. | 1200 | ..... |
| Keller † † | 1901 | Furnace with carbon electrodes, 1200 H. P. | Iron ore and cast iron. | 3800 | 18.00 to 21.00 |
| Harmet | 1901 | Furnace with carbon electrodes. | Iron ore. | 3600 | 6.00 (not total price) |
| Schoeider | 1901 | Furnace without carbon electrodes. | ..... | ..... | ..... |
| Ruthenburg † † † | 1901 | Furnace with carbon electrodes. | Iron ore. | ..... | ..... |
| Conley | 1902 | Furnace with carbon electrodes. | 1 Iron ore.<br>7 Cast iron and waste steel. | 1000<br>1042 | 12.00<br>28.50 |



250 HP STASSANO FURNACE (DARFO, 1903)

and the power required for the reduction of the ore is placed at about the same figure in both cases.

For the preparation of crucible steel the electrical method

* As for some time we have given considerable space to this latest and still more or less experimental branch of electrometallurgy, the above paper by an authority of the rank of Dr. Goldschmidt, who has spent considerable thought and time for studying this matter, should be of great interest to our readers. As far as the information given by Dr. Goldschmidt has not already been published in ELECTROCHEMICAL INDUSTRY, we give his paper nearly in full. The information given by Dr. Goldschmidt on the Stassano and Kjellin processes is quite complete. Taken together with this paper, the articles published in former issues of this journal, on electrical steel processes should represent a good resume of the present condition of this branch of electrometallurgy.—ED.

** See also ELECTROCHEMICAL INDUSTRY, 1903, pages 247, 363.

*** See also ELECTROCHEMICAL INDUSTRY, 1903, page 376.

† See also the article by Heroult on another page of this issue.

†† See also ELECTROCHEMICAL INDUSTRY, 1903, page 162.

††† See also ELECTROCHEMICAL INDUSTRY, 1903, page 202.

* This table has already been published in ELECTROCHEMICAL INDUSTRY, March, 1903, page 247, table 1. It is, therefore, not here repeated, nor the tables on the thermochemistry of the reactions, data on actual operation and analyses of the steel produced, all of which may be found on page 247 and 248 of our March issue. On page 247, left column, the fourth one from the bottom should read: Si-trace. In the right column, under Thermo-Chemistry, General, read CO, instead of $C_{sg}$.—ED.

** See ELECTROCHEMICAL INDUSTRY 1903, page 162.

*** See the article by Heroult himself on another page of this issue.

will in all probability be the most profitable. Heroult prepares in his furnace from a mixture of cast iron and steel clippings, a tool steel of best quality, which up to the present, especially in England, has found a good market.

The refined steel has the following composition:

S = 0.007 per cent.
P = 0.003 per cent.
Mn = 0.15 per cent.
Si = 0.003 per cent
C = 0.60 to 1.80 per cent.

Crucible steel of best quality is, however, also obtained according to the method of Kjellin, a Swede. The furnace (see Electrochemical Industry, 1903, p. 376) forms a transformer in which the fluid steel takes up the low-voltage secondary current with high-current density, whilst a high-pressure alternating current is led to the primary.

This method avoids the use of electrodes entirely, and is purely a smelting operation in which pure cast iron (about 25 per cent), and wrought iron are smelted together; the first may advantageously be brought into the hearth in fluid form. In its essential points this method has been worked out in the Gysinge Iron Works and appears, as also does the method of Heroult, to be technically quite satisfactory.

In the following table, an attempt is made to estimate the cost from data obtained in actual practice.

Cost of Preparation of Steel (Crucible Steel Quality) by Kjellin's Method.

Four thousand one hundred kg. steel are produced in twenty-four hours with 225 hp. (165 kw.), hence 1000 kg. require 1320 hp.-hours.

| | |
|---|---|
| Power (the cost of 1 hp.-hour being assumed as 0.375 cent) in round numbers | $5.00 |
| Charge | 32.50 |
| Mould | 0.25 |
| Repairs and brick work | 2.08 |
| Depreciation and interest | 0.56 |
| Wages | 2.50 |
| Total without cost of business management, license, etc. | $42.89 |

The cost of the charge (pure charcoal pig iron and soft iron) is taken as $32.50 per ton. A charge of specially pure materials or the addition of chromium, wolfram or molybdenum would naturally raise this item of cost considerably. The charges for repairs and brick work appear very small, indeed it is said that these would be even less if fluid cast iron and a larger furnace were employed.

A great advantage of the process seems to be in the fact that the fire gases do not come into contact with the steel, not even by diffusion. This being so, a lining of silica or magnesia stone can be employed; and finally large charges can be heated at once. The ordinary steel crucibles hold generally only 30 kg., and at most 50 kg. metal, while with the furnace at Gysinge about 1 ton can be worked. The cost of erection of a furnace, with capacity as given in the table and including electrical plant, but not source of power, is given as 15,000 crowns, Swedish. The following analyses made at Gysinge illustrate composition of various steels prepared thus:

| | I. | II. | III. |
|---|---|---|---|
| Carbon | 1.45% | 1.20% | 0.95% |
| Silicon | 0.47% | 0.74% | 0.35% |
| Manganese | 0.49% | 0.46% | 0.33% |
| Phosphorous | 0.011% | 0.013% | 0.014% |
| Sulphur | 0.010% | 0.010% | 0.015% |

In the discussion which followed Danneel asked what is the difference between the furnace of Heroult and Keller. Goldschmidt replied that there are still differences regarding the patents between the two inventors. Replying further to Engelhardt, he said that the high figures of cost of the Gysinge process refer to cold charges.

Gin imparted the information that he has constructed a furnace for which he claims a high economy. The furnace is built in the form of a long canal with narrow cross section, ending on each side in steel blocks kept cool by internal circulation of water. The passage of a current of necessary strength through the conducting molten metal develops sufficient heat to keep the whole mass fluid and to impart to it the temperature most suitable for purification of the metal. The large cross section of the metal blocks at the ends of the metal canal prevents there the formation of a high temperature, and this is aided by the circulation of the cold water. In order to give the furnace a suitable form the canal is bent like the filament of an incandescent lamp.

The balance of the report will be published in our next issue.

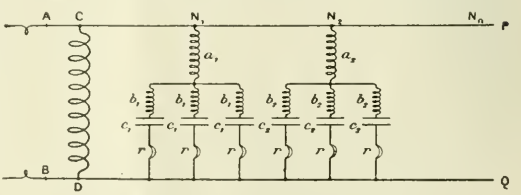
# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

By Carl Hering.

## Industrial Electrochemistry.

*Production of Nitric Acid by Electric Discharges.*—In a paper read before the *Société Internationale des Electriciens* at Paris, J. de Kowalski describes his method and apparatus for the production of nitrous vapors from the nitrogen of the air. He states that as early as 1899 he had observed that the yield of nitrous vapors increases considerably with the frequency of the alternating current used to produce these discharges. The experiments of MacDougall and Howles had shown that a yield of 36.6 grams of nitric acid per kilowatt resulted with a current of 0.2 ampere. Kowalski and Moscicki, working with a frequency of between 5000 and 6000 cycles per second, have obtained 43.5 grams of nitric acid per kilowatt-hour with an arc of the same intensity. They have also found that when the intensity of the current in the arc diminishes, the relative quantity of nitrous vapors increases. The length of the arc is also not without influence upon the yield. With a current of about 0.05 ampere, a difference of potential of 50,000 volts, and a frequency of 6000 to 10,000 cycles per second, they obtained a maximum of nitrous vapors for the energy employed. They have obtained 52 to 55 grams of nitric acid per kilowatt-hour, which yield could be nearly doubled by adding about 50 per cent of oxygen. Their apparatus is shown in the adjoining figure. A and B are the terminals of




NITRIC ACID BY ELECTRIC DISCHARGES.

a high-potential transformer. AP and BQ are two parallel conductors, connected by groups $N_1$ and $N_2$. Each of these groups consists of a self-induction coil *a* in series with three parallel self-induction coils *b*. Each of the latter is in series

with a condenser C and an arc *r*. The two wires AP and BQ are also connected by a large self-induction coil CD. The coil *a* is intended to prevent the oscillating discharges from reacting on the main transformer. The self-induction of this coil is calculated so that its impedance, which is very great with the high frequency currents which are produced in the charge and discharge of the condensers, shall be relatively small for the current of ordinary frequency coming from the transformer. The whole system produces a phase lead, as a compensation for which the large coil CD is arranged. The author works with a tension of 50,000 volts at the terminals of the principal transformer. One of the most important parts of the apparatus is the condenser. After experiencing considerable difficulty in this respect, they now use small glass tubes silvered on both sides. Exact measurements have demonstrated that the loss of energy in these condensers does not go above 1 per cent. The small self-induction coils for the high frequency also have to be constructed very carefully.

*Electrometallurgy of Aluminium.*—An article entitled *Note sur l'Electrometallurgie de l'Aluminium*, by GIN, appears in the issues of June 30 and July 15 of the *Journal de l'Electrolyse*. The author first discusses the choice of an electrolyte and lays down the conditions to which the latter has to conform. He then calculates the theoretical voltage of decomposition of a bath of aluminium fluoride, supposing that the fluorine does not escape as such, but in the form of tetrafluoride of carbon, mixed with a more carburetted fluoride. By his formula he obtains 57,450 calories and 2.49 volts, which Minet found experimentally to be 2.5 volts. For Hall and Heroult's alumina electrolyte he finds 50,650 calories and 2.19 volts. He found experimentally 2.3 volts as an average of four observations. For aluminium sulphide he finds 29,350 calories and 1.27 volts. The author concludes from these figures that for the preparation of one kilogram of aluminium from the electrolytes considered above, the energy consumed will be approximately given by one of the following formulas, in which Kf, Ko and Ks are "variable quantities, between 16 and 19 kilowatts." For $Al_2O_3$ (Kf + 8.5) kilowatt-hours; for $Al_2O$. (Ko + 7.5) kilowatt-hours; for $Al_2S_3$ (Ks + 4.4) kilowatt hours. The maximum difference is therefore in the neighborhood of 5 kilowatt-hours; at the present price of electric energy, as furnished by the great water-powers, this difference represents hardly a few centimes per kilo of aluminium. In summing up the author states that the cost price of aluminium depends much less on the more or less easy decomposition of the electrolyte than on the cost of this electrolyte. The economic problem is therefore more of a chemical than of an electrochemical order. The author concludes by stating that while electrolyzing a mixture of artificial cryolite and aluminium sulphide, stopping the operation before it was finished, he observed the presence of a subsulphide of aluminium in the electrolyte, which was well crystallized and of a light cinnabar red color. He is now studying this compound.

*Electrolytic Manufacture of Vanadium and Its Alloys.*—A paper on this subject has been presented before the Fifth International Congress of Chemistry, at Berlin, by GUSTAVE GIN, the well-known French electrometallurgist. The principle of the process depends on the great conductivity of vanadium trioxide, and on the facility with which trifluoride of vanadium is obtained, by attacking the trioxide with fluorine in the presence of carbon. Ferrous fluoride, dissolved in molten calcium fluoride, is electrolysed with an anode composed of an intimate mixture of carbon and vanadium trioxide. The cathode is constituted by a bath of metallic iron. The fluorine is stated to attack the trioxide of vanadium at the anode, with the formation of vanadium trifluoride, which dissolves in the calcium fluoride. The fluoride is then electrolysed in its turn, which sets free metallic vanadium at the cathode. The fluorine which is liberated at the anode forms the vanadium trifluoride again. The electrodes are prepared by calcining vanadic acid in the presence of carbon, which is then mixed with a certain quantity of retort carbon and pitch, and compressed into rods in an apparatus similar to that used for the manufacture of carbon electrodes. The electrodes are kept away from air and moisture, under a layer of dry material, until they are used. The anode of the furnace is formed of a bundle of the above electrodes, and certain dispositions have to be adopted, on account of the high melting temperature of vanadium and the alloys which contain it in notable quantity. For alloys containing more than 25 per cent of vanadium, the cathode cross section must be notably smaller than that of the anode. A good yield and a sufficiently fluid bath is obtained with an average current density of 2 amperes per sq. cm. of anode cross-section and 6 amperes per sq. cm. of cathode surface, the voltage being between 11 to 12. A certain quantity of fluorine is lost by being transformed into gaseous carbon tetrafluoride, and, therefore, there has to be, from time to time, an addition of ferrous fluoride. The iron which serves as cathode is introduced into the bath in the metallic state, a little at a time, after each cast of ferro-vanadium. If iron is not introduced into the bath, it is possible to obtain nearly pure vanadium, but the casting of the latter is very difficult, and it has to be extracted in solid form. The author hopes, also, to apply this process under the same conditions to alloys of vanadium with other metals, such as copper, aluminium, manganese, etc., wherein it suffices to replace the cathode of iron by one of the metals which are desired to be incorporated into the alloy. The paper is reprinted in *L'Eclairage Electrique*, June 27.

*New Carbide Works in Switzerland.*—The electrical equipment of the carbide works at Flums, Switzerland, is described and illustrated in the *Electrochemist and Metallurgist*, July, by F. C. PERKINS. The plant at the power station, which has a capacity of 2400 hp, and is situated at a distance of 1.8 kilometers from the carbide works, consists of three large turbines of the horizontal type, each directly coupled to an 800-hp revolving field alternator of the three-phase type. Polyphase current is generated at a potential of 5000 volts, with an efficiency of 93 per cent. The alternators are so dimensioned that they may also be used as single-phase machines, running also at 5000 volts. The power transmission line consists of six copper conductors insulated by porcelain and mounted on iron tops, or caps, upon wooden poles. The furnace house of the carbide plant is 30.7 meters long, 12 meters wide, and 10 meters high, the floor, roof and walls being of iron and cement, and above the furnaces is an upper deck, also constructed of iron and cement. This deck construction is extended over the whole length of the furnace room. The materials are placed in the furnaces by an electrically-operated elevator. The transformer house, which is located near the furnace room, contains three single-phase transformers, which reduce the line current from 5000 to 65 volts for use in the furnaces. The transformers are of the oil-water cooled type, of a capacity of 850 kw each. The connections to the furnaces are only 8 meters long, the secondary conductors being arranged for single-phase current from the transformers; the copper conductors have a cross-section of 4800 sq. mm. and a total weight of 4.5 tons for each group of six furnaces. Current of 2200 to 2500 amperes is employed in each furnace. The numerous carbon electrodes are regulated by hand by chain gearing. From two and a half to three hours are required to produce the carbide, and it remains another hour or an hour and a half in the furnace, in order to cool off. There are eighteen furnaces in continual operation, arranged in groups of six or of four, twelve of them being usually in operation at the same time. The carbon electrodes required, per ton of carbide produced, are said to weigh about 30 kilograms. The plant comprises, also, the usual facilities for handling and storing supplies, etc.

*Industrial Electrolysis of Water.*—In a recent meeting of the Societe Belge d'Electriciens, M. JOTTRAND, director of the Société l'Oxhydrique, in Brussels, read a paper on the Garuti process for the industrial electrolysis of water, which is ab-

stracted, with diagrammatic illustrations, in the *Revue de l'Electricité*, July 15. The diaphragm used by Garuti is of metal, perforated by a number of holes of very small diameter, which do not allow the gas to pass, on account of capillary action. The use of such a diaphragm enables the voltage to be reduced to 2 or 2.5 volts, the metallic diaphragm not acting as intermediate electrode, if the potential does not overstep 3 volts. It is claimed that the production is 0.4 liters of hydrogen and 0.2 liters of oxygen per ampere hour, with an expenditure of 4.166 kw for a cubic meter of gas, 2-3 of hydrogen, 1-3 of oxygen. The electrolyte is a caustic soda or caustic potash solution. The gas which is obtained is stated to be very pure; the small amount of hydrogen in the oxygen is gotten rid of by passing the gas through an apparatus composed of pipes heated to a red heat, which effects the combustion of the hydrogen. The last part of the article is devoted to the description of an improved oxyhydrogen blow-pipe.

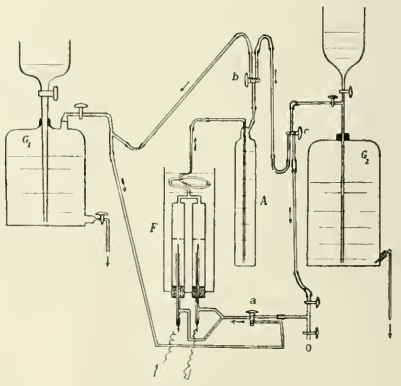
*Polishing and Plating of Metals.*—A long extract from a manual under this title, by Hawkins, is given in the *American Jeweler*, July. The first part deals with the question of lining tanks for electroplating purposes. Detailed instructions are given for lining the tanks with asphalt which contains a little pitch, in order to get a lining which will be thoroughly satisfactory. Particular emphasis is laid on the necessity of getting the corners well filled, by pouring in hot lining and following with a hot flat iron until the lining has melted into one solid piece; successive layers will not do, it must be one solid piece. Whether the surface is rough, as in eastern practice, where it is sanded with clean, white sand before the asphalt lining cools, or whether it is smooth, as is generally preferred in the west, makes no difference. The acid dipping jars and the jars for various pickles and dips should be arranged in a large wooden tank of shallow depth. Care should be taken not to have the waste pipes from this tank too small, as it is sometimes required to empty it very quickly, in case a pickle jar, or dip, has been upset, or in case a sudden change of work requires absolutely fresh water in the tank. In the latter case, valuable time may be lost while waiting for a 100-gallon tank to refill. The hot side of the tank should have a steam pipe open at the bottom and reaching nearly to the bottom of the tank. The steam must be clean, and should come directly from the boiler; it will not do to use exhaust steam, because it contains oil, and the rinsing water must be kept clean. The pressure must be such as to heat the water nearly to the boiling point, while a supply of cold water is constantly fed in. Much valuable time is said, by the author, to be lost by neglecting this point, as, in many places, pickling and dipping cannot begin for several hours after starting in the morning, on account of lack of steam. Detailed instructions are given in regard to arrangements of the various dipping tanks, the potash tank and the scrubbing tanks for the plating solutions, and several illustrations of such tanks are given. Solutions should be skimmed off occasionally with a suitable skimmer, to remove the dust and grease before hanging the work in the solution. Cyanide solutions will not require this very often, but nickel solutions have a tendency to form a greasy scum, which must be removed each morning before hanging in the work, in order not to cause spotty deposits, or peeling off of the work. A method is given for performing this conveniently by means of tissue paper. The extracts will be continued in subsequent issues of that journal.

*The Electric Furnace.*—The serial previously mentioned in the Synopsis on the electric furnace, its origin, development and forms of application, is continued by Adolphe Minet in the *Electrochem. Zeitsch.*, July and August. The types described in the July issue are the well-known Borchers type with cooled metallic cathode and two types by Willson, also well known. Then follows the description of several carbide furnaces, among which are the Bullier, Gin & Leleux, Siemens & Halske and the Willson Aluminium Company furnaces. The August issue brings, besides the furnaces types of Memmo, the well-known Parker and the Laval furnaces, a description of a new type of furnace, which is said to have been recently patented in Germany and bears the name of Neuburger-Minet. This furnace is said to be so constructed that it is possible to run it by blast-furnace gas, power gas, or electricity. It consists of a central reaction chamber, with heating chambers and regenerative chambers. The position of the electrodes varies according to the nature of the reactions and the degree of purity which is desired for the product of the furnace. If this must be free from carbon, the electrodes are situated above the central chamber. If the product can stand a certain admixture of carbon, the electrodes are brought nearer to the charge. The nature of the walls of the reaction chamber varies according to the product desired.

*Production of Ozone.*—In the issues of July and August of the *Electrochem. Zeitsch.*, Dr. O. Kausch continues and concludes his illustrated serial on the production of ozone by electrolysis, describing, among others, the apparatus of Tindal, Yarnold, Verley, Otto and Siemens & Halske.

### Theoretical and Experimental.

*Isolation of Argon from Atmospheric Air.*—Two methods have been proposed for the separation of argon from the air and especially from the nitrogen of the latter, the first being the absorption of the nitrogen by chemical means, as by metallic magnesium, and, the second, the passing of electric sparks through the air, thereby converting the nitrogen into nitrous compounds. Lord Rayleigh and Ramsey used the second method, passing the sparks between two electrodes arranged inside of a large glass bulb, which was half filled with caustic soda solution and the other half of which was occupied by the mixture of atmospheric air and oxygen. This arrangement is somewhat complicated, and the danger of losing all of the




ISOLATION OF ARGON.

argon, if the glass bulb cracks, is considerable of a drawback. Another arrangement has, therefore, been elaborated by A. Becker, which permits continuous running of the apparatus and the production of any desired quantity of argon with perfect security. He describes the arrangement in the *Zeitsch. f. Electrochem.*, July 23. The apparatus is shown in the adjoining cut. $G_1$ and $G_2$ are two gasometers, filled with air and a few liters of oxygen. The air is passed from $G_1$ into the spark apparatus F, which consists of a vessel of sheet zinc, in the interior of which there are arranged two brass tubes of about 5 cm. diameter and 28 cm. length. The two tubes communicate at the top and lead to a lead coil, which serves as a cooler. The vessel F is filled with cold water. In the interior of each brass tube there is arranged a brass disc with a central opening, which serves as one electrode of the spark gap. This construction is for the purpose of forcing the gases into a nar-

row stream, while they are passing the spark gap. The other electrode is formed of a thick, pointed copper wire, fastened in a glass tube at the bottom. The glass tube has a side tube, through which the air is introduced into the apparatus. The terminals of the secondary of a transformer are connected with the lower ends of these copper wires. From the spark apparatus the gases pass into an absorption apparatus A, and from there into the gasometer $G_2$. After a certain time, the two-way cocks a, b and c are reversed and the air now travels in the opposite direction through the apparatus. The author found that the best results were gotten when long sparks were obtained and when the air passed the spark gap at a certain, exactly-determined speed, in order to avoid a recombination of the products, as well as a too rapid passage. As the absorption proceeds, fresh air, or oxygen, can be introduced at o. The cooling water in F has to be removed from time to time, but a continuous flow is not necessary. It was possible to obtain, in a few days, with two of these apparatus, two liters of gas, which, treated again by sparking, gave about 600 cc. of argon.

*Decomposition of Cyanide Silver Plating Baths*.—The processes which take place in cyanide silver plating baths, while they are in use, have been studied very little. The cause of the loss of cyanide, more especially, which makes a regeneration of the baths necessary after a certain time, has not been ascertained. There are, also, investigations wanting whether a bath containing silver chloride can be used. E. JORDIS and W. STRAMER tried to find out something about these questions by comparing silver baths which were running on a large scale, and published their results in the *Zeitsch. f. Electrochem.*, July 9. They experimented with three baths, one of which contained silver chloride and the two others silver cyanide. The chloride and one of the cyanide baths were used for silver plating, while the third bath was used for comparison. The authors found that the loss of cyanide and the increase in carbonate is always greater with the working bath than with the idle one. In the bath containing chloride, the loss in cyanide and the increase in carbonate was still much greater, so that the latter bath had to be regenerated oftener. This increased formation of carbonate, the authors think, can only have been brought about by an increased anodic oxidation, the causes of which are the chlorine ions. This disadvantage is offset by the advantage that the resistance is only two-thirds of that of the pure cyanide bath, and that it can, without detriment, especially without danger of sliming up the anodes, run up to a higher content of carbonate, with higher currents. It has been found that after a while more cyanide disappears than is equivalent to the amount of carbonate found; consequently, there must have been secondary reactions. The authors state that in the text books of plating there is frequently found the assertion that the products of decomposition are necessary in the silver bath to obtain a good deposit, and that new baths did not work well. It is, therefore, recommended to add a part of the old bath or potassium formate and ammonia. The authors state that this is not necessary, that the fresh bath is entirely satisfactory, if it is started with pure materials, and if the operator knows how to use a volt and ammeter.

### PRIMARY AND SECONDARY BATTERIES.

*The Jungner-Edison Accumulator*.—The Swedish chemist, Jungner, has patented several accumulator constructions and, in the opinion of DR. M. SCHOOP, he apparently recognized, before Edison, that nickel oxide, if suitably supported upon a carrier, is a practical depolizer. The English and the German patent offices have been influenced by Jungner's objection to materially curtail Edison's patent claims. For these reasons, it seems to be more accurate to speak of a Jungner-Edison accumulator than *vice versa*. He publishes, in the *Electrotechnische Zeitschrift*, of August 6, the results of an investigation conducted with a Jungner accumulator and an ordinary lead storage battery, in order to compare their behavior during charge and discharge, their capacity, the changes of temperature and concentration of the electrolytes, and the relations between capacity and current strength. The Jungner accumulator had five negative and four positive electrodes, both formed of perforated supports of nickel-plated sheet steel, shaped like pockets, in the interior of which the active material was contained. The material of which the pockets are constructed is the same for both electrodes, but the active material is different, being nickel oxide and cadmium, or iron in a very finely divided state. Mixed with suitable liquids, they are introduced into the pockets in the form of a paste.

He summarizes his results as follows, for the lead and the Jungner accumulator: In the former, according to Faraday's law, 3.66 grams of sulphuric acid is combined or liberated, as the case may be, for each ampere hour; the solution, therefore, changes its specific gravity, its conductivity and volume. In the latter the alkaline electrolyte does not change its chemical and physical nature during any phase of the charge and discharge, and merely carries the oxygen from one electrode to the other; small amounts of liquid are, therefore, sufficient. The accumulator can be compared to an oxygen reservoir. In the lead cell, during discharge, free acid diffuses toward both sides into the pores of the plates; the concentration, therefore, decreases in the middle. In the Jungner cell, the electrolyte diffuses, during discharge, out of the pores of the nickel electrode into those of the cadmium electrode, while the density between the plates is not changed. As the active mass is present in the form of powder, and the distances between the plates can be very short, the diffusion takes place very quickly. For the good working of the lead accumulator it is necessary to adhere strictly to the average density of the acid, as given in the instruction, and to avoid a rise of temperature of the acid above a certain limit, about 40° C. The best conducting caustic solution in the Jungner cell does not conduct as well as the best conducting acid, and has the tendency to absorb $CO_2$ from the air. The good working of the electrodes, on the contrary, is independent within very wide limits of the concentration of the caustic solution. On the lead plate, as well as on the peroxide one, a local action takes place, which is the more violent the denser the acid is; the lead accumulator is, therefore, comparable with a water reservoir which leaks a little. The caustic solution in the Jungner cell does not seem to attack either the electrode support nor the active materials. The active materials in the lead accumulator adhere exceedingly well to the conducting support and conduct very well. The internal resistance of the lead accumulator is small and amounts to only several thousandths of an ohm, even in the smaller types. The active substances in the Jungner cell have to be brought into pockets, as they do not harden, and they have a bad conductivity. The internal resistance is two to three times as great as in the lead accumulator. The capacity in the latter is dependent upon the time intervening between charge and discharge, the temperature and density of the electrolyte, the strength of the charge and discharge current, the porosity and the thickness of the plates. Besides the quantity and structure of the active mass, the capacity is also determined by the volume of liquid present. In the Jungner cell the capacity is influenced by the strength of the discharge current to a much smaller degree, and depends chiefly on the amount of active material; the influence of the temperature of the electrolyte on the capacity is insignificant. The loss of potential, however, amounts to 35 to 40 per cent, and still more with slow discharges, while the loss of potential in the lead accumulator usually does not go above 12 per cent. The materials for the Jungner cell are expensive; a caustic solution of 30 per cent is about four times as expensive as accumulator acid; but Mr. Schoop might have added here that the volume of the caustic solution per ampere hour is, or may be, made much less, and that the total cost of the liquid is not an important part of the whole. The efficiency of the

Jungner cell is about 80 per cent in ampere hours and 65 per cent in watt hours, while the efficiency for the lead cell is, on an average, 85 to 90 per cent in ampere hours and 75 per cent in watt hours. The taller the vessel is, in the case of the lead cell, the sooner will a difference of concentration take place in the acid between the plates, by which certain local reactions are started. The space needed for the Jungner cell is about one and a half times as much as for the lead cell of about the same weight and watt-hour capacity, but there is no objection to make the height of the vessel anything desired. The author concludes that for the present the alkali accumulator has, besides the uncontested advantages just as many serious disadvantages. It must, however, not be forgotten that the lead accumulator needed twenty years to reach its present stage of technical development, and there is no reason why the alkali accumulator should be less capable of development.

Mr. Schoop's comparisons are of interest, but it should be understood that they refer only to the two particular cells which he used; the results do not necessarily apply to all alkaline cells of that type; it is not to be assumed that the alkaline cell which he used was the best that could be constructed; the results should therefore not be assumed to apply to the form made in this country by Edison, at least not until they have been confirmed for this particular cell. Moreover, such comparative figures depend on so many conditions that they may be totally different for different discharges. The only really fair comparison is to discharge each at its best normal rate, and then find the capacity in useful watt-hours per pound, and the rate in watts per pound; the weight should be the total, including everything necessary. The watt-hours efficiency and other data should then be given for those discharges. For automobile work one should not lay too much stress on the efficiency, as a cell of poor efficiency might well cost much less per ton-mile of live load over a period of five or ten years, than one of high efficiency.

### Miscellaneous

*Engineering Science and Chemistry.*—In an interesting paper before the recent annual meeting of the German Society of Engineers, Professor W. Ostwald called attention to some problems, the solution of which is of extreme importance, and demands the closest co-operation of the engineer, and the chemist. After touching briefly on electrochemistry as an exemplification of a combination of chemistry and engineering, he remarked that just at the present time we are standing at the beginning of a fundamental change in the production of mechanical from chemical energy. This change is being brought about by the development of the internal combustion engine, which is now taking place. This seems to be another instance of the law which meets the investigator everywhere, namely, that the simplest thing always comes last. It is indeed much simpler to change the chemical energy contained in the fuel directly into mechanical energy by burning it with the necessary amount of air, than to do the same thing by means of steam as a connecting link, which process only utilizes a comparatively small part of this energy, and in which the supply of the water, its change into steam and the getting rid of the exhaust steam, are just that many sources of unnecessary complication. The question of the gasification under the best conditions obtainable with regards to the fuel under consideration, is primarily a chemical one, conditioned, however, everywhere by mechanico-technical considerations. The preponderant direction in which development will take place, is, according to Professor Ostwald, toward the establishment of large central stations, which will distribute their power either as electric current, or as gas for power purposes. He then takes up the chemical question of gasification based on the reactions $H_2O + C = H_2 + CO$ and $2H_2O + C = 2H_2 + CO_2$. The question as to how the second reaction, which does not furnish CO, could be increased, is one of chemical dynamics, and is to be answered by saying that there is practically only one possibility of doing it, namely, the lowering of the temperature. The conditions of the equilibrium are discussed, and it is shown that even the gasification of pure carbon is a complicated phenomenon, which becomes more complicated still if the water contents of the fuel, for instance, in the case of moist lignite or peat, enter into consideration. Touching now upon the question as to how the energy generated in the large power station can be distributed in a form most handy for the consumer, Professor Ostwald comes to the conclusion that electrical energy is for this purpose far superior to all other forms of energy, and that it will always be that form which best corresponds to the demand of the public, to have things in such shape that they need a minimum of care and attention. But apart from the question of gasification there are a number of great problems presented to the chemist, namely, the utilization of the by products obtained in the gasification. Attention is called to the fact that the enormous coal tar industry is based upon a consumption of coal, which does not reach the one-hundredth part of that burned under the boilers. If it is imagined that all the latter coal will be gasified, the perspective of the tremendous amount of the by products to be dealt with, and the accompanying possibilities is bewildering. The ammonia also, which is formed from the nitrogen in the coal, will play an important role in agriculture. Professor Ostwald mentioned the fact that he has lately succeeded, with the help of his assistant, Dr. Brauer, to convert ammonia quantitatively into nitric acid, which process could be carried out on a large scale. This reaction, up to the present, could only be performed quantitatively as a lecture experiment. Reviewing his preceding remarks he calls attention again to the necessity of co-operation, as neither the engineer nor the chemist alone will be able to do justice to the demands of the problem. The paper is reprinted in the *Zeitsch. f. Calcium-Carbid Fabrication*, July 10 and 17.

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

### Electric Furnaces and Furnace Products.

*Process of Smelting Metals and Metal Compounds.* G. Egly, Charlottenburg, Germany. Patent 733,578, July 14, 1903. Application filed Jan. 14, 1903.

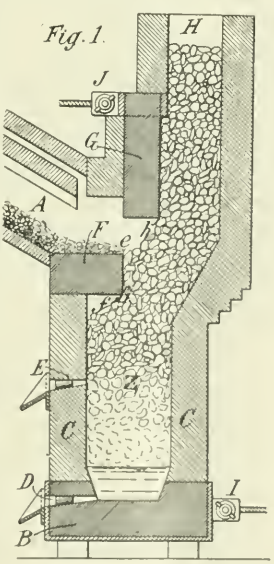
The purpose of the invention is to prevent metals reduced in the electric furnace from taking up carbon from the electrodes, thereby diminishing their value. The means proposed for the prevention of this is the formation of a slag or scoria, which is to be arranged on top of the lower electrode so as to prevent the molten material from coming into contact with it. The slag or scoria is to be composed of a substance which, though a good conductor of electricity, is chemically undecomposable to as high a degree as possible, and, furthermore, in the presence of carbon and metals, will not melt or will only melt with difficulty. The invention is to be applied especially to the reduction of nickel from its oxide. The inventor states that magnesia is a material especially well fitted for the formation of such a scoria, as it is in remarkable degree indifferent to

high temperatures. To the magnesia is added a substance which conducts electricity in the cold or at red heat, and which is chemically inert, non-volatile and undecomposable at the high temperatures to which it will be subjected. As examples of such substances are cited fluorspar, titanium dioxide, titanium monoxide and the like. These substances are added to the magnesia in the proportion of about 20 to 25 per cent by weight. The apparatus shown in the specification in which the melting process is to be carried out, has the shape of an ordinary melting pot of fire clay, the bottom of which is formed of an electrode. The latter is covered by a layer of the scoria, and on top of this is a layer of molten metal. A second layer of slag formed in the operation of melting separates the other electrode, which is represented as a rod, from the metal. After the lower electrode, which in the case of direct currents is the cathode, is covered by a scoria of the nature described, it is allowed to cool to a red heat and then the reduction of nickel is carried out preferably by direct current of low density. The current density employed is stated to be preferably about 2 amperes per square centimeter, although good results may be obtained at lower current densities. The process may also be used for the smelting of metals, for instance, of nickel or wrought iron waste from which cast steel is to be manufactured. In this case so much scorifying material is to be added to the metal to be smelted that a covering scoria will be formed in a short time.

*Electric Furnace.* P. L. T. Heroult, La Praz, France. Patent 733,040, July 7, 1903. Application filed March 27, 1902.

The principle of this latest furnace construction of the well-known electrometallurgist depends upon the treatment of ores which have been previously fused until they have reached a pasty condition or are sufficiently softened to descend progressively into the furnace. The furnace is not intended to operate alone, but works in connection with another. It is illustrated in the adjoining Fig. 1. The furnace consists of a carbon crucible B, surmounted by a well C, which has walls of refractory material. Openings are provided at D and E, the upper one serving as a slag hole and the lower one as tapping hole. The reduction of the ores takes place in this well, which contains a high column of coke or other fuel through which the current passes. The ore enters into the furnace by the passage A, leading from the furnace in which it has been previously brought to a pasty condition. This pasty mass becomes mixed with the descending column of coke and is reduced on its way down to the bottom of the crucible. As the carbon disappears in reducing the ore, the coke column is fed at the top from a reserve contained in the upper part of the furnace. The fuel which causes reduction of the ore, and which really forms one of the electrodes of the furnace, therefore flows into the furnace in a continuous manner as the operation goes on. On top of one of the walls of the well C is placed a block F of carbon, which forms the floor of the preparatory furnace mentioned above; by its means the ore is delivered right into the middle of the coke column. The block is so arranged that it can be easily replaced when it is worn out. Another carbon block G, of variable form, is arranged so as to constitute one of the walls of the upper structure H, through which the fuel is introduced. The terminals of the supply circuit are connected to the crucible by means of the connection I and to the block G by means of the connection J. The block or so-called false electrode F establishes a short circuit, with the block G through that portion of the carbon column which is above the well, so that the two points *e* and *f* are at intense heat. It is stated that owing to this intense heat, the floor which the block F forms, is cleared from the fused or pasty ore so that there can be no accumulation of ore which might obstruct the column. On the other hand at *h*, there is obtained a high temperature which superheats the descending carbon. The gases escaping from the reduction of the ore pass through the passage A into the preparatory furnace. The upper carbon blocks are stated to seldom require to be replaced if they are shielded from the air, a condition which is fulfilled, as they are always surrounded by the gases resulting from the reduction of the ore. The furnace described is stated to be especially suited to the production of cast iron, ferro silicon, ferro manganese and other like products.

Fig. 1.




HEROULT FURNACE.

*Process of Removing Silica From Coke.* Charles M. Hall, Niagara Falls. Patent 733,389, July 14, 1903. Application filed Sept. 24, 1902.

In this specification Mr. Hall outlines his method for the treatment of the carbon electrodes which are to be used in the manufacture of aluminium. For this purpose they should be substantially free from silicon, as the latter element is taken up by the aluminium and spoils its quality. The process consists, broadly stated, in mixing with the carbonaceous material to be treated a metallic fluoride, for the purpose of forming with the silicon contained in the material a gaseous fluoride of silicon, which will go off during the baking. A number of different fluorides have been used, sodium fluoride, cryolite and fluorspar giving good results. The coke to be treated is first pulverized, and mixed with sufficient sodium fluoride to remove all, or the greater part of the silicon as silicon fluoride. The material is then mixed with a suitable binder and formed into blocks or any other desired shape, and subjected to a baking process in an electric furnace. The latter contains a core of any suitable material adopted to be raised to a regulated temperature by preferably an alternating current. The articles are insulated from each other while they are being baked. One of the materials thus treated was Pocahontas coke, with 4.4 per cent ash. The principal constituents of the latter were as follows: $SiO_2$, 4.98 per cent; $Fe_2O_3$, 1.53 per cent; $Al_2O_3$, 28.27 per cent; CaO, 3.45 per cent; $TiO_2$, 3.51 per cent; $Na_2O$, 2.25 per cent, with small quantities of manganese and magnesium oxides. One hundred and thirty parts by weight of this coke were mixed with 60 parts of hard pitch, 7 parts of tar and 10 parts of sodium fluoride, after which the mixture was thoroughly baked, having been previously formed into blocks. The carbons were then examined, and it was found that the ash had been reduced from 4.4 per cent of the total weight to 3.51 per cent. Of this latter the titanium dioxide was reduced to 3.31 per cent, and the sodium oxide was increased to 1.378 per cent; but at the same time the silica was reduced to 18.32 per cent, or less than one-half the amount in the coke before it was treated. The carbons were thus well adapted for use in electrolysis. Instead of mixing the coke, fluoride and pitch and forming them into the desired shape before baking, in this way combining the purification and the preparation of the electrodes in one process, the purifying steps may be carried out separately by heating the mixture of coke and fluoride alone.

## APPARATUS AND PROCESSES FOR THE ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

*Apparatus for the Electrolytic Decomposition of Alkali Chlo-*

*rides.* C. Thurnier, Geneva, Switzerland. Patent 734,312. July 21, 1903. Application filed June 25, 1902.

The specification describes an apparatus for the electrolysis of alkaline chlorides, which belong to the diaphragm type of apparatus, having even two diaphragms instead of one, as the inventor proposes to use a middle compartment. The inventor refers first at length to the various disadvantages encountered in such apparatus where pressure is used on the middle compartment in order to prevent the products of electrolysis in the anode and cathode compartment from reacting upon each other. He then states that the novel feature of his invention is based in the fact that caustic soda is considerably more soluble in the solution of chloride of sodium than the chlorine. It is, therefore, neither necessary nor advisable to exert an equally great pressure by means of the central liquid on the anode and cathode liquids. Further, it is claimed to have been shown by experiments that very little chlorine passes through the diaphragm if the pressure of the liquid is equally great on both sides of the porous partition between the anode and the central cell. But it is proposed to even destroy this small quantity of chlorine at the moment of its passage through the diaphragm by an arrangement by which a quantity of caustic soda, exactly corresponding to the small quantity of chlorine is directed against it, and further by heating the electrolyte which lies between the two diaphragms to a sufficiently high temperature. These two precautions are evidently not enough to destroy that very small amount of chlorine, and, therefore, the inventor takes still a further precaution, namely, that of adding a certain amount of high metallic oxide, more particularly cobalt superoxide to the electrolyte in the middle compartment. It seems as though in spite of the pressure on the central compartment there was soda diffusing into the middle compartment from the cathode side and chlorine from the anode side, for they are expected to form sodium hypochlorite in the middle compartment, which it is the function of the cobalt superoxide to reconvert into NaCl + O. The apparatus with its accessories, in which this process is to be carried out, is represented in Fig. 2. It consists of an electrolytic cell which is divided into three compartments, the anode cell *a*, the intermediate compartment *m*, and the cathode compartment *k*, which is subdivided into three parts again. An anode *t* of carbon is arranged in the anode compartment, the material of the cathode is not mentioned, but it appears from the sketch as though a plate of iron were intended to be used, as only one connection is shown for the three superimposed cathode cells. The three cathode compartments are arranged in such a manner that the upper one receives the fresh chloride of sodium solution through pipe *h*, while it delivers a solution already somewhat charged with

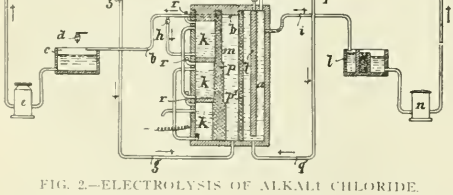


FIG. 2.—ELECTROLYSIS OF ALKALI CHLORIDE.

alkali into the middle cathode compartment, where it is still further enriched before passing into the lowest part. From there it is drawn off for further treatment. Hydrogen is stated to escape by pipes *r*, *r*, *r*. According to the increasing contents of alkali in the three compartments of the cathode side of the apparatus, the porous wall of the middle compartment toward the cathode is also made in three thicknesses, being thickest in the lower part. *s* in the anode compartment is supposed to be a pipe leading off the chlorine, though what prevents the solution from spurting out there under the conditions illustrated is hard to see. The middle compartment solution which has become cold in the apparatus, passes out through pipe *b* into a tank *c*, where it is replenished if necessary through valve *d*. From there it runs through a heating apparatus *e*, whence it is lifted to a feed tank f, arranged at a height determined according to the degre of hydraulic pressure it is intended to carry. The solution returns again to the middle compartment by means of pipe *g*. From the anode compartment a pipe *i* leads to a tank *l* in which the salt contents of the solution are automatically replaced. The solution then flows into a lifting device, which elevates it to the feed tank *o*, whence it is returned to the anode compartment. Cobalt superoxide, as stated above, is introduced into the middle compartment, preferably by saturating pieces of pumice with nitrate of cobalt, then rendering them incandescent, and after that packing them loosely into the middle cell. An apparatus like the above, with its many complications, is hardly likely to prove a serious competitor to the simple mercury processes.

*Manufacture of Peroxide of Lead.* E. Querenfeldt, Duisburg, Germany, Assignor to Chemische Fabrik Griesheim Electron, Frankfort, Germany. Patent 734,950, July 28, 1903. Application filed June 25, 1901.

The invention relates to a process for the direct conversion of lead oxide (litharge, red lead and the like) into lead dioxide. This conversion is effected by subjecting to electrolysis an emulsion of lead oxide with a concentrated solution of an alkaline chloride or the chloride of an alkaline earth. Electrolysis is carried out at a pressure of about 3 volts, and a corresponding current intensity, the anode being of platinum carbon and the like, and the cathode of any metal. The latter is preferably fitted into a frame over which parchment paper or another suitable material is stretched, in order to separate it from the anode. No trace of chlorine is stated to be evolved at the anode, while hydrogen is given off at the cathode. The lead oxide is kept in constant motion, and under the influence of the current gradually becomes brown, and towards the end of the electrolytic process black-brown. The conversion is stated to take place quantitatively in the time calculated from the current intensity required for the oxidation. The inventor thinks that as lead oxide is but very imperfectly oxidized by hypochlorous salts, it is to be supposed that the hypochlorite formed during electrolysis does not act directly on the lead oxide in the emulsion, but on the compound of alkali and lead, $Pb\begin{matrix}ONa\\ONa\end{matrix}$, which must be formed as an intermediary product and pass into solution. The latter presents an advantage in so far as it is not necessary to effect a preliminary solution of the lead oxide in hydrochloric or acetic acid. The alkali which is always present in small quantities in the electrolytic process will dissolve corresponding quantities of the compound of alkali and lead, which are at once converted into lead dioxide and alkaline chloride by the hypochlorite or chlorine, according to the reaction $Pb\begin{matrix}ONaCl\\ONa\end{matrix} + Cl = PbO_2 + 2\ NaCl$. The peroxide being formed in a state of emulsion, assumes a pulverulent form. The process is conducted in an earthen vessel, placed in a water bath, which is heated by a steam coil, and a stirring device keeps the emulsion in constant motion.

*Electrolytic Manufacture of Chlorates and Perchlorates.* P. Lederlin, Chedde, France. Patent 732,753, July 7, 1903. Application filed July 11, 1902.

The present invention relates to an improvement in the manufacture of chlorates and perchlorates by electrolysis, in order to obtain a high yield of the current. The inventor claims to have discovered that the addition of a chromate or bichromate to the electrolyte can be dispensed with, if care is taken that the liquid is kept non-alkaline by convenient additions of dilute hydrochloric acid. He states that by making these addi-

tions, it is easy to obtain a yield, for instance, in chlorate of sodium of from 0.50 to 0.55 grams per ampere-hour. By making the additions continually a yield of 0.58 to 0.61 grams per ampere-hour is obtained, which corresponds to 90 per cent of the theoretical result. The chlorate is obtained periodically from the liquid by refrigeration and crystallization, and the solution replenished with fresh chloride. The precise amounts of hydrochloric acid which it is proposed to add to the electrolyte are not stated in the specification.

*Electrolytic Apparatus for Recovering Metals From Their Compounds.* C. E. Baker and A. W. Burtwell, Cleveland, Ohio. Patent 734,499. July 28, 1903. Application filed Nov. 11, 1902.

The apparatus is based upon the use of metallic mercury, an absorbent for the metals to be recovered, and is more especially to be employed for the production of metallic sodium and chlorine from sodium chloride solution. The apparatus is illustrated in Fig. 3. A vessel of sheet iron 5 is provided with a cement lining 6 and filled with a solution of sodium chloride, for which inlet pipes 8 and outlet pipes 7 are provided. Carbon electrodes 11 serve as anodes, and pipe 10 is intended to carry away the chlorine. Metallic mercury 12 covers the bottom of the apparatus and flows by means of pipes 13 and 15 into two retorts 2, which have outlets 17 and are heated by Bunsen burners 16. The mercury is vaporized in these retorts, and passes through pipes 18 and 19 into a condensing worm 3, whence it returns to the bottom of the apparatus. Pipe 13 is introduced into the apparatus through an insulating bushing 14.

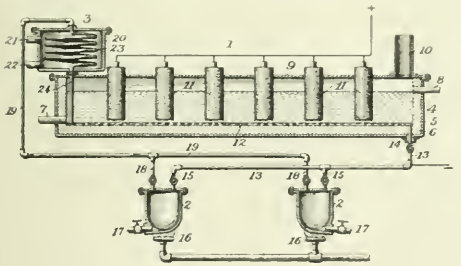


FIG. 3.—PRODUCTION OF SODIUM FROM SODIUM CHLORIDE

and is connected with the negative source of the current, thus making the mercury the cathode of the apparatus. The metal which was amalgamated with the mercury, i. e. metallic sodium, remains in the retorts and is removed through outlet 17, or otherwise. The inventors have evidently lost sight of the fact that they have to retort enormous quantities of mercury in order to get a little sodium. It is not possible to keep the amalgam under the influence of the current long enough to enrich it to any considerable extent, as it cannot be kept from reacting with the electrolyte, and thus forming disturbing compounds with their attendant disadvantages on the electrolysis of the sodium chloride. Besides that it is hard to see how they can get the scum of amalgam on the surface of the mercury down into the little pipe which leads to the retorts.

*Basket for Holding Tin Scraps.* M. Laernoes and John Dunn, Streator, Ill. Patent 734,894. July 28, 1903. Application filed Nov. 25, 1902.

The specification describes an improved construction of such a basket, especial attention being paid to making it strong and durable. The basket is made of perforated sheet metal reinforced at the corners by angle-irons. The latter are extended over the side walls of the basket in the form of yokes, and provided with laterally extending handles, by which the basket is supported in the electrolyte, as they rest on the sides of the electrolytic vessel. One handle serves as conductor of the current and makes contact with a conducting rail arranged on one side of the electrolytic box. Between the shank of the handle and the upper ends of the yoke there are interposed layers of tin or tin foil, which serve as fuse, in case a current of greater strength than desired passes through the electrolyte. Another layer of tin foil is placed between the handle and the current-conductor rail.

*Metal Anode.* H. E. Starrett, Chicago, Assignor to the Hanson & Van Winkle Co. Patent 733,602. July 14, 1903. Application filed Dec. 19, 1901.

The anode described in the specification is of elliptical cross section, in order to insure an even disposition of metal on the cathode opposed to such anode, and to overcome the well-known tendency of the deposit to become thicker at the edges. Another object of the invention is to provide frequent passages between adjacent anodes for the circulation of the electrolyte, and to get the anode free from sharp angles and corners at the edges. The inventor has found in practice that such an anode having a cross section of elliptical form, i. e. having a long diameter two or three times its shorter diameter, is best for the average plating bath.

*Electrolytically Coating Iron with Zinc.* E. Goldberg, Moscow, Russia. Patent 733,028, July 7, 1903. Application filed April 17, 1902.

The invention consists in adding to the electrolyte in which the iron is to be plated, a compound containing nitrogen in combination with an organic radical. Suitable compounds for the invention are the amines, amides, cyanides, nitrites or like compounds in which the nitrogen is attached directly or indirectly to an organic radical. The pyridene bases are stated to have given the best results. The process is carried out in the following manner. The electrolyte consists of a solution of 10 grams of zinc chloride and 10 cc. of pyridene to one liter of water. Enough hydrochloric acid is added to dissolve the double salt of zinc chloride and pyridene which is formed. A current not exceeding 0.2 amperes per square decimeter is required. Zinc is used as anode and the object to be coated with iron as the cathode. It is stated that a pure white, dense and bright deposit of zinc is obtained in this manner.

*Process of Nickel Plating.* T. A. Edison, Llewellyn Park, N. J. Patent 734,522, July 28, 1903. Application filed Feb. 14, 1902.

The object of the process is to produce an adherent coating of nickel on iron or steel surfaces, and it is applicable to sheets or other forms which are subsequently drawn, stamped or pressed, or to articles which already have their ultimate shape. The articles of iron or steel to be plated, are first covered in an ordinary nickel-plating bath, with a thin coat of nickel. They are then stacked together and introduced into a cast-iron chamber or clay retort, in which a non oxidizing atmosphere is produced by passing through an inert gas, preferably hydrogen. While the current of gas is passing the articles are heated to a bright yellow heat which is said to be sufficient to weld the thin covering of nickel to the iron or steel backing, so that the film will not crack or flake off during the subsequent mechanical treatment to which the articles are subjected. The passage of the inert gas is continued until the articles have cooled down below the point of oxidation. It is claimed that nickel articles can be produced in this way more cheaply than the tinned ware, as the coating of nickel on the former is very much thinner than the coating of tin on the latter.

STORAGE BATTERIES.

*Secondary Battery.* W. Gardiner, Chicago, Ill. Patent 732,842, July 7, 1903. Application filed Jan. 23, 1902.

The battery consists of an outer tray, rectangular and relatively shallow, of iron, copper or other suitable metal, the bottom of which is covered with copper wire gauze. Upon the bottom thus formed are placed a number of longitudinal and transverse insulating strips of hard rubber, which also extend up the sides of the tray. A second tray similar in shape to the first, rests upon these insulating strips. This inner receptacle may be made of copper and plated with silver or other suitable material and is provided on its bottom with a network of

wires, which may be of silver or silver plated. This inner receptacle is filled with active material, in a relatively hard, but porous form, consisting of relatively pure silver thoroughly mixed with mercury and molded to the desired form. When the elements of each cell are assembled in this manner the cell is closed by a sheet of the same metal as that of the outer tray, and the cover soldered on. The electrolytic fluid may now be poured in through an aperture left in the outer tray for that purpose. The electrolyte preferably used consists of a strong solution of zinc oxide and an alkali, such as potassium or sodium hydrate. The outer tray, with its lining of wire gauze serves as the negative electrode, and the inner tray with its active material is the positive electrode. In charging the cells, zinc is liberated and deposited in the outer cell on the wire gauze, while the oxygen set free is said to be combined and included in the active material in the inner tray.

*Method of Preparing Electrolytes.* W. Gardiner, Chicago. Patent 732,843, July 7, 1903. Application filed Jan. 23, 1902.

The specification describes a method of preparing the electrolyte in that form of storage batteries, in which the electrolyte is formed of a solution of oxide of zinc in sodium or potassium hydroxide. The usual manner of preparing this electrolyte consists in the solution of zinc oxide in a solution of sodium or potassium hydrate, but as the latter is only capable of dissolving a comparatively small quantity of zinc oxide, it is necessary to employ a large volume of solution for a given capacity of the cell. The inventor's method consists in dissolving oxide of zinc, made by the wet process in a strong solution, preferably of caustic potash. This solution is then placed in a cell having suitable electrodes, and electrolyzed until the greater portion of the zinc contained in it is deposited upon the positive electrode. The solution is then removed and a second quantity of oxide of zinc dissolved in it, after which it is replaced in the cell and electrolyzed again, until the zinc has been deposited as before. This process may be repeated until sufficient zinc to equal the capacity of the desired battery is deposited upon the positive electrode. The solution used to dissolve the oxide of zinc may then be removed and a strong fresh solution of pure caustic potash and water, containing no zinc oxide, may be substituted. The battery is then ready for charge and discharge in the performance of work. During the discharge the zinc accumulated upon the electrode in the prior charges upon the positive electrode dissolves or is taken up in the solution, so that after the discharge is completed a far greater quantity of zinc is dissolved or contained in the solution than could be possible by the old process. It is stated that a cell of this character may be charged very much quicker than an ordinary cell of its kind, inasmuch as the electrolyte contains a great excess of zinc, which is held in solution in an unstable condition and which is therefore deposited almost immediately when the charging current is applied. The method is evidently intended to furnish an electrolyte for the cell constructed by the same inventor, which is described above.

*Active Material for Electric Accumulators.* Alida L. Rosenthal, Administratrix of S. A. Rosenthal, deceased, London, England. Patent 733,918, July 14, 1903. Application filed May 8, 1903.

The invention consists in the employment of urea sulphate, $(CO(NH_2)_2)\ 2H_2SO_4$ as a binding agent for the active material of electric accumulator plates where the oxides of lead, finely powdered—such as, for example, litharge, minium or red lead, but preferably litharge—are used. The invention also comprises the process of manufacturing and the employment of a small quantity of lead sulphate in combination with the urea sulphate. It is claimed to have been shown by experiments that in employing a solution of urea sulphate in water of suitable strength, and by mixing this solution with the finely powdered lead oxide, an extraordinary hardening effect is produced upon the combination. In order to prevent a too rapid hardening and to allow the molding into the desired form, the urea sulphate solution is first mixed with dilute sulphuric acid, preferably of 1.2 specific gravity. This mixed solution is then incorporated with the lead oxide until a stiff paste is obtained, which is compressed or molded into the desired form. After the paste plate has set, a frame of lead may be cast around it to complete the electrode, or it may be filled into a lead grid in the form of stiff paste. One and one-half parts of urea sulphate to four to six parts of water, with an addition of 5 per cent of lead sulphate, has yielded a suitable solution. One part by volume of this solution is mixed with one and a half to two parts by volume of a solution of sulphuric acid of 1.2 specific gravity. It is stated that when the pasted plates are formed by the usual electrolytic action, the paste becomes very coherent, and has a hard and toughened texture and surface, and that on this account a battery formed with these plates has been found to be specially adapted for use for electric traction, electric cars, and such purposes where a high discharge output and durability are required.

### Galvanic Elements.

*Zinc Cup for Primary Batteries.* V. G. Apple, Dayton, O. Patent No. 731,422, June 23, 1903. Application filed March 23, 1903.

The invention is designed to overcome some of the ill effects due to the employment of zinc cups for portable, and more especially dry batteries, which cups are made of rolled sheet zinc, bent into cylindrical form and soldered together. The rolling of the zinc sheets hardens the surface and prevents the proper action of the exciting fluid on the zinc, and local action is set up at the joints where the solder is employed, owing to the presence of two dissimilar metals. The inventor now proposes to cast the zinc into molds, and in order to overcome the tendency of cast zinc to show blow holes, he performs the casting operation under pressure. The zinc is heated up to its melting point (about 420 degrees) and cast under a pressure of 125 pounds to the square inch. The inventor prefers a corrugated form of cup, thus providing a maximum of active surface in the interior of the cup, and at the same time getting the cup somewhat yielding, so as to permit expansion and contraction of the liquid contained in it.

### Miscellaneous.

*Process of Preserving Beer.* F. Crotte, New York. Patent 734,305, July 21, 1903. Application filed Jan. 19, 1900.

The inventor states that the principle of this process consists in the application of the cataphoric action of the electric current. He fills a long tube, which is preferably made of copper, silvered externally, with an antiseptic, such as boric acid or the U. S. P. standard solution of peroxide of iron or other preservative, either solid or in solution. This tube is then introduced into the barrel containing the beer which is to be preserved. It is provided with a knob at the bottom and is connected with one of the poles of a powerful spark coil. Its length is such that it reaches nearly to the bottom of the barrel. Opposite this long tube on the outside of the barrel, there is arranged the other electrode, also preferably of copper and provided with a knob. A sponge soaked with water or the same antiseptic solution as that contained in the tube may or may not be in contact with the second electrode. The connections are so made that the tube forms the positive electrode and the inventor claims that when the circuit is in such condition that the silent or brush discharge passes between the electrodes, cataphoric action will result, the effect of the high-tension current being to convey the preservative substance in the tube in infinitesimal quantities through the tube wall into the beer. The current is passed through the beer for a period of from five to ten minutes. In order to further insure the destruction of the organic life in the beer, it is stated to be preferable to supplement the passage of the high-tension current by passing a current of low tension—100 to 110 volts—through the beer for five to ten minutes.

## CURRENT NOTES.

Drexel Institute.—We have received from the Drexel Institute, of Philadelphia, a circular concerning their reorganized School of Electrical and Mechanical Engineering. The two courses, one in electrical and one in mechanical engineering, are separate, and each is of two years' duration. The subjects of instruction in the first year are the same for both courses. They include higher mathematics, advanced physics, technical chemistry, and most of the distinctively engineering subjects which are pursued in common by the two classes of students. At the beginning of the second year the student makes a choice between the two branches of engineering, and thereafter devotes his time to the special work—electrical or mechanical—which he has elected. For admission a good high school or equivalent education is required. The tuition fee is $75 per year.

American Electrochemical Society.—At the meeting of the Board of Directors of the American Electrochemical Society, held at Philadelphia on August 7, the following gentlemen were elected members of the Society: George M. McKee, Hinckley, N. Y.; W. J. Hammer, New York; J. A. Macdonald, Philadelphia, Pa.; F. A. Lidbury, Niagara Falls, N. Y. The names of the following gentlemen will come up for election at the September meeting of the Board of Directors. M. L. Davies, Bay City, Mich.; Charles M. Perry, Pawtucket, R. I.; T. E. True, Elizabeth, N. J.; Thomas B. Stillman, Hoboken, N. J.; L. M. Dennis, Ithaca, N. Y.; Alan A. Claflin, Littleton, Mass.; Heyward Scudder, Boston, Mass.; J. H. Beal, Scio, Ohio; Ernst Fahrig, Philadelphia, Pa.; J. G. White, New York; Anthony F. Gref, New York; Carl C. Curtis, Sandusky, Ohio; Wilson G. Howell, New York; W. R. C. Corson, Hartford, Conn.; Louis Duncan, Boston, Mass.; Ervin Dryer, Chicago, Ill.; C. D. Brown, Windsor, Conn.; James A. Wotton, Atlanta, Ga.; J. L. Merrill, Pittsburg, Pa.; M. W. Hanks, Pittsburg, Pa.; J. M Kent, Kansas City, Mo.; E. A. Sjoestedt, Sault Ste. Marie, Ont., Canada; H. N. McCoy, Chicago, Ill.; E. H. Clapp, Boson, Mass.; George T. Scholl, Philadelphia, Pa.; Franz Meyer, New York; Alonzo C. Bell, New York; Stephen Gardner, Chicago, Ill.; Edmund O. Schweitzer, Chicago, Ill.; H. B. Smith, Worcester, Mass.; G. C. Rowe, Havana, Cuba; Hamilton Wingate, Forest Hill, London, England; Wilber T. Earl, Niagara Falls, N. Y.; George W. Bauer, San Francisco, Cal.; Shigekan Tadu, New York; R. T. Conger, Pittsfield, Mass.; H. S. Wilson, Pueblo, Mexico; Ernest B. Le Mare, Manchester, England.

The Effect of Impurities in Salt in Mercury Cathode Processes.—The third volume of the Transactions of the American Electrochemical Society contains an interesting paper by Dr. J. Wallace Walker, and Charles S. Paterson, on "The Influence of Some Impurities in Salt Upon the Yield of Caustic Soda by the Amalgam Process." As this paper has been read by title, and was therefore not abstracted in our report of the meeting, a brief account of it should be of interest here. With chemically pure sodium chloride the loss (as represented by the amount of hydrogen evolved at the mercury cathode) is constant, about 1.5 per cent, so that the yield of caustic soda is almost theoretical. If a single impurity like K, Ca, Mg or Fe is added to pure sodium chloride, the loss remains small, except in the case that the single impurities are Ni or Co, which cause considerable loss; but as these are not generally found in commercial salt, this is of no great industrial importance. The most important fact brought out by the investigation is that the addition of an extremely small amount of Fe to commercial salt, already containing traces of calcium and magnesium, is sufficient to cause a loss of as much as 30 per cent, and that this loss does not increase much with the concentration of iron. Another observation made is that the amalgam formed, when chemically pure salt is used, shows no immediate signs of decomposition in the cell when the current is turned off; when iron is present in the salt, however, decomposition is immediately noticeable. The principal result of importance for practice is that with a salt containing small quantities of the impurities common to natural salt, such as calcium, magnesium or potassium, the loss in the amalgam process will be very small. If, however, in addition to these, the cell should become contaminated with the minutest traces of iron salts, such as might be produced by the action of the chlorine on any iron or iron compounds in the apparatus, the effect may become so great as to render the plant useless.

## CORRESPONDENCE.

### PROF. HABER'S REPORT ON ELECTROCHEMISTR IN THE UNITED STATES.

To the Editor of Electrochemical Industry.

Sir—Permit me to say a few words in reply to some criticism on my report, printed in the July number of Electrochemical Industry.

Mr. Charles S. Bradley considers my account of the work of the Atmospheric Products Co. as of the kind that "tends to injure the commercial development." I have never, in anything I have published, had such a thought, and I do not see how such construction can be placed on my impartial remarks on the Atmospheric Products Co. I very highly appreciate the great success of this company in the production of nitrous fumes from air, and I have emphasized my admiration for their work in my report. The result of the work of the company in transforming the nitrous fumes into strong nitric acid is, however, still unknown to me; but should Mr. Bradley convince me of his success in this respect, none will be more glad than myself to acknowledge the very high merit of the commercial value of the process.

Dr. Joseph W. Richards protests against my comparison of the system of education in American and in German universities. In my report I referred to the fact that my view agrees with that of prominent professors in American universities—H. Muensterberg, E. D. Perry—and I can point to the notes of Dr. Theodore W. Richards and Dr. Alexander Smith, which are published, with that of Dr. Joseph W. Richards, in the July number of your journal.

Dr. J. W. Richards thinks that what I have said may be valid for those universities which I visited, but I should not have generalized. While in the United States I visited the following universities: Harvard, Johns Hopkins, Cornell, Leland Stanford, Universities of Michigan, of Wisconsin, of Chicago, of California, of Pennsylvania, the Case School of Applied Science, and the Massachusetts Institute of Technology.

I should think that a view based on a visit of these twelve institutions justified some generalization. Moreover, the two general features which Dr. J. W. Richards mentions, "the low entrance requirements, and the low plan of undergraduate instruction," became evident to me, not only from my visit to the universities, but from conversations with colleagues, and from the publications of the universities I have collected, which report these facts.

I therefore think that my esteemed colleague, Dr. Joseph W. Richards, will not consider it unfair if I say on my part, that to me it seems that he practices in some regards "the scientific use of imagination" to fill up gaps in his knowledge concerning my information, and sometimes with results far from the truth. F. Haber.

Karlsruhe Germany.

## BOOK REVIEWS.

Analysis, Detection and Commercial Value of the Rare Metals. By J. Ohly, Ph. D. Denver: Industrial Printing and Publishing Company, 1903. 216 pages. Price, $3.00.

The plan of this book is to take up each of the rare metals separately, and to give for each its history, chemistry and commercial aspects, mineralogy, detection, qualitative determination and quantitative estimation. Following out this plan, the

book contains twenty-nine chapters, devoted to the following twenty-nine elements: Tungsten (wolfram), niobium (columbium), thallium, tantalum, molybdenum, tellurium, platinum and the platinum metals, palladium, rhodium, osmium, ruthenium, iridium, selenium, germanium, uranium, indium, gallium, vanadium, beryllium (glucinum), thorium, zirconium, cerium, lanthanum, ytterbium, scandium, titanium, lithium, cæsium, rubidium. The chapters average a little over six pages each, although tungsten has eight pages, molybdenum eight, uranium ten, and vanadium thirteen.

Following these are a number of appendices, giving the analysis and commercial treatment of complex ores of vanadium and uranium, tungsten and molybdenum, and tests for some of the more common metals.

The work contains much information, such as could be obtained only by a diligent search through large works on chemistry, and in addition many items of recent appearance, and many which are here printed for the first time. The commercial information given is reliable and much more practical than is usually found in chemical works. One feature, from the scientific point of view, is the entire absence of references to other works, or to the literature of the subject, and therefore, as a necessary consequence, the inclusion of all absolutely necessary details. This characteristic of the work makes it the more valuable to persons who do not read French and German, or who do not have access to a scientific reference library, and of less value to those who *can* get at the original sources of information. The book is therefore to be particularly recommended to the commercial and practical man, and to the scientist out of touch with a large scientific library.

Introduction to the Rarer Elements. By Philip E. Browning, Ph. D. New York: John Wiley & Sons, 1903. 157 pages. Price $2.50.

This work is prepared from material used by the author in giving a short lecture course at Yale University, and is intended as an introduction to the study of those elements not always taken up in a general course in chemistry. The elements treated of are (with the exception of five pages given to the newly discovered gases of the atmosphere) identical with those catalogued by Dr. Ohly (see previous review), and the order of treatment is to give for each element its discovery, occurrence in nature, methods of extraction of its salts in the laboratory, preparation of the element, properties, characteristics of its compounds, quantitative estimation and separation from other elements. Under each of these headings the information given is comparatively brief and lacks detail to such an extent, particularly in the analytical portions, as to be comparatively useless as a practical guide to work by. The lack of detail alluded to is partly compensated for by numerous references to the original articles, to which the student or investigator may refer for actual details of manipulation, but this reduces the practical value of the information actually given from the rank of a hand-book to that of an index.

The book is, therefore, in one way, a valuable introduction to the further and more complete study of these elements. The lack of detail is a sharp limitation on the value of the work, which would not be felt so much by the reader who had at his elbow a good chemical reference library, but which would render the book practically valueless to the isolated chemist or metallurgist not so provided. To the student in the laboratory, or the investigator well equipped with works of reference and having access to files of the chemical journals, the book is full of valuable information and rich in suggestions of further study.

## ELECTROPLATING DYNAMOS.

In our February issue, 1903, page 230, we gave an illustrated description of electroplating dynamos built by the Holtzer-Cabot Electric Co., of Boston, Mass. From an interesting and neatly illustrated bulletin (No. 146), issued recently by this company, we gather the following additional information.

The table given below gives particulars as to the standard sizes of plating dynamos built by the Holtzer-Cabot Co. All machines are provided with a combined oil pan and sub-base with belt-tightening device. A suitable pulley and field regulator is also furnished with all machines. The E 1-6 and No. 1 and 2 platers generally supply single tanks, so the shunt winding is used to secure simplicity; on the larger units, however, compound winding is used. These machines are wound for 6 volts at the speeds given, although in any case a range of from 4 to 8 volts may be obtained by field and speed manipulation. Voltages outside of the limits named are to be obtained by special windings. Separate excitation is earnestly recommended on all of these large machines, even if it involves the use of a separate exciter, since in this way the simplicity of a shunt machine is secured with the voltage stability of a compound machine. The machines are usually belted and run at a speed which is purposely made low to do away with as much of the friction loss as possible, and also to prevent the brushes from cutting the commutator, a difficulty often encountered in high-speed machines of this type. The two halves of the armature deliver their outputs in parallel to the terminal blocks at the full voltage of the machine.

| Size No. | H. P. Required to Drive. | Approx. Speed. | Number of Poles. | Output in Amperes at 6 Volts. | Sq. Ft. per Hour. | | | No. Gals. | | | Pulley | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Nickel. | Brass or Copper. | Silver. | Nickel. | Brass or Copper. | Approx. Shipping Weights. | Diameter. | Face. |
| E 1-6 | ¾ | 1800 | 2 | 20 | 6 | 3 | 10 | 80 | 40 | 100 | 2 | 1½ |
| 1 | ⅝ | 1300 | 2 | 35 | 12 | 5 | 17 | 140 | 70 | 200 | 2 | 2 |
| 2 | ⅞ | 1200 | 4 | 65 | 24 | 9 | 37 | 260 | 125 | 250 | 3 | 2 |
| 3 | 1½ | 1000 | 4 | 125 | 41 | 18 | 62 | 500 | 500 | 400 | 4 | 2½ |
| 4 | 2½ | 900 | 4 | 250 | 83 | 35 | 125 | 1000 | 400 | 700 | 5 | 3 |
| 5 | 4¼ | 800 | 4 | 400 | 133 | 57 | 200 | 1600 | 750 | 1000 | 6 | 3 |
| 6 | 7 | 700 | 6 | 700 | 233 | 100 | 350 | 2800 | 1200 | 1400 | 7 | 4 |
| 7 | 9¾ | 650 | 6 | 1000 | 333 | 143 | 500 | 4000 | 1800 | 1700 | 8 | 5 |
| 8 | 12½ | 600 | 8 | 1400 | 466 | 200 | 700 | 5600 | 2700 | 2000 | 10 | 6 |

It is, of course, impossible to give more than a general idea of the size required for certain purposes. The figures given here relate to a salt solution in the case of the nickel, and acid solution in the case of the copper, both of rather a low density. The distance between electrodes was about 4 inches, and the work was a plain surface of brass, one square foot in area. The plate was .0004 of an inch in the case of the nickel and .001 of an inch in the case of the copper, the time being one hour in each case. The temperature was 70° F. and the deposit was purposely made of a finely grained nature, such as is used in buffed work. A modification of any of the conditions named would cause some variation in the quantity of current required, so that the data here given will serve as a guide only in a very general way.

The dynamo should, if possible, be placed in a clean, cool and dry place. It is, of course, advisable to place the machine as near the tanks as possible, but never in an elevated position where it will be subjected to the fumes from the tanks. It is well to have a good tight partition between the plater and the plating room. The machine should be set on a substantial foundation, and all vibration eliminated, if possible. Care in this respect will add to the life of the machine.

## GRINDING ORES.

Electrometallurgy is the most recent branch of metallurgy and may justly be considered to be still in its infancy. But the rapidly increasing use of the electric current for power purposes in a metallurgical plant will surely lead to an increasing use of electrochemical methods in metallurgy; the distinct and undeniable advantages which electrochemical methods possess for certain work in metallurgy, are quite evident, and it is certain they will more and more be taken advantage of when electric current is already available in a plant for other purposes, such as power and lighting. It is generally at a rather late stage that electrochemical methods enter into a metallurgical process; what Nature gives us, are ores, and they must

first undergo a mechanical and chemical treatment before they are ready to be dealt with by an electrochemical method. The success of an electrochemical method often depends upon a judicious and suitable preliminary treatment by mechanical and purely chemical means.

The simple process of grinding ores is one of the first and most important in any metallurgical process, and for this rea-

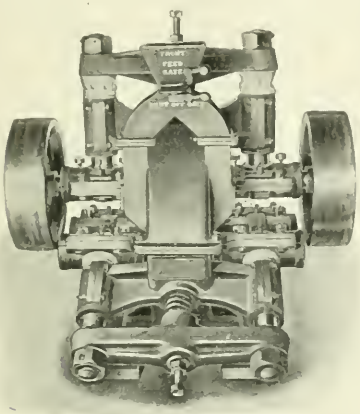


FIG. 1.—KENT PULVERIZER.

son our readers will be interested in the following description of the Kent Mill, made by the Kent Mill Co., of New York, which, while in extended use in metallurgical plants in general, has also already found successful application in connection with electrometallurgical works.

The Arlington Copper Co., of Arlington, N. J., have installed two Kent mills for grinding the ore to 20 mesh through these mills; the ore is then roasted and undergoes a chemical treatment, and is then passed to the electrolytic vats for producing a high-grade electrolytic copper.

In cyaniding processes—whether in the final step the gold is precipitated by zinc shavings or by electrolysis—the pul-

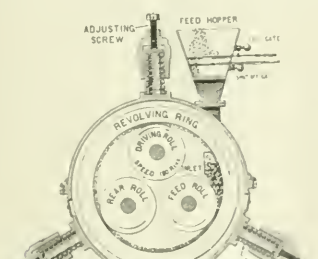



FIG. 2.—INTERIOR OF KENT MILL.

verizing of the ores so as to give a uniform powder suitable for subsequent treatment is of the greatest importance. The Helena Gold Mining Co. uses the Kent mill in connection with a cyaniding plant, and have found its adaptability for this class of work thoroughly satisfactory.

Figure 1 shows a Kent quartz pulverizer for grinding any quartz, ores, cement, phosphate rock, etc. The interior of the Kent mill, as shown in Fig. 2, consists essentially of a revolving ring and three rolls pressing against its inner face; these are the only four wearing parts; the rolls are convex, and the ring is concave and tracks on the rolls. The rolls are supported yieldingly by means of springs and the rolls again support the ring. In this way the four crushing parts are free to move to pass iron or uncrushable objects, and are cushioned to take up shock and vibration and prevent crystallization or breakage.

The rock falls from the inlets onto the inner face of the ring. Centrifugal force holds it there in a layer an *inch deep*. It revolves with the ring, and passes under the rolls. The rolls are pressed by the springs outwardly against the rock on the ring with a pressure adjustable to 20,000 pounds by the screws against the springs. The rolls roll over the rock, crushing it against the ring. The crushed rock flows off each side of the ring into the casing and falls to the discharge.

The body of rock between the rolls and the ring makes 90 per cent of the rock abrade on itself in crushing, thus reducing the wear on the wearing parts enormously.

## REAGENT BOTTLES WITH INDELIBLE LETTERS.

Messrs. EIMER AND AMEND, of New York City, have been appointed sole agents for *Stender Reagent Bottles*, the only make in the world whose black letters are guaranteed to be absolutely indelible against any reagent.

## PERSONAL.

Prof. WILHELM OSTWALD, of Leipzig, the famous German chemist whose biographical sketch and portrait were published in the February number of ELECTROCHEMICAL INDUSTRY, delivered an address in German at the recent opening of Prof. Jacques Loeb's newly built biographical research laboratory at Berkeley, Cal. Prof. Ostwald is now touring this country, and intends to sail again for Europe in the middle of September.

Dr. W. H. WALKER, of Boston, Mass., has now returned from Europe, where he attended the Fifth International Congress of Applied Chemistry, of which he was elected a vice-president. Dr. Walker also visited various electrochemical plants to study recent electrochemical developments abroad.

Mr. WILLIAM J. HAMMER, whose very elaborate lecture on radio-active, phosphorescent and fluorescent substances, on the properties of selenium and on the treatment of disease by ultra violet light, was received with such profound interest at the joint meeting in April of the American Institute of Electrical Engineers and the American Electrochemical Society, has received a cordial invitation from the *Faraday Society* to deliver a similar lecture before this society in London.

## INDUSTRIAL NOTES.

The firm of J. BISHOP & CO., refiners of platinum, whose plant at Sugartown, Pa., was destroyed by fire on January 30 last, have erected a new plant at Malvern, Pa. The new building is a commodious two-story brick structure with increased facilities for supplying platinum sheet and wire in all forms for special purposes. The concern is one of the oldest in this line in this country, having been established in 1842.

We have received from the WESTINGHOUSE ELECTRIC AND MANUFACTURING CO. circulars No. 1067 on air blast transformers and 1037 on engine type alternators.

The neat and profusely illustrated catalogue of Assayers' and Chemists' Supplies for 1903, issued by the DENVER FIRE CLAY CO., of Denver, Col., contains on the first 206 pages a very complete list of general chemists' and assayers' laboratory supplies; twenty four more pages deal with special chemical apparatus for analytical work, and the balance of the catalogue (170 pages) with outfits for assayers and prospectors, school sets of chemical apparatus; collections of minerals; models and charts; scientific books; fire brick and fire clay material; and chemicals and pure reagents.

## DIGEST OF U. S. PATENTS

Prior to July, 1902.

*Compiled by Byrnes & Townsend,*
*Patent Lawyers,*
*National Union Building, Washington, D. C.*

### White Lead by Electrolytic Methods.

292,119. January 15, 1884. Johann K. Kessler, Milwaukee, Wis.

The electrolytic tank is divided by an impervious partition extending from the bottom nearly to the top; electrolyte consists of a solution of sodium or potassium acetate filling both compartments. The anode, consisting of lumps of lead, is placed upon one side of the partition, a body of lead serving as the cathode being placed in the other compartment. Upon passing the current, lead acetate and the alkali hydroxide are formed in the respective compartments; these are mixed in a separate vessel, precipitating hydrated lead oxide. This is maintained in suspension by an agitator and carbon dioxide injected. The precipitate of white lead is filtered off, washed and dried and the regenerated solution returned to the electrolytic tank.

292,753. January 29, 1884. Johann K. Kessler, Milwaukee, Wis.

A square vat is filled with an alkali metal acetate solution and provided with a central carthode of sheet lead, around which are grouped the lead pigs constituting the anode. Spongy lead is electrodeposited on the cathode and from time to time removed, washed and pressed, and carbonated by a mixture of air, steam and carbon dioxide. The white lead so produced may be converted into red lead by the action of air at red heat.

359,352. March 15, 1887. Edward V. Gardner, London, Eng.

To convert blue lead into white lead exposes it to commingled vapors of acetic water and air. The basic acetate and hydrate formed are subsequently carbonated by carbon dioxide. The action is accelerated either (1) by placing electro-negative substances in contact with the lead; for instance, the lead may be supported on carbon grids; the electro-negative material may be in the form of carbon or may be platinized; (2) by passing electric discharges through vapors either in chamber or before entry; (3) by using ozonized air.

414,935. November 12, 1889. Turner D. Bottome, Hoosick, N. Y.

Electrodes of lead in solution containing 6 per cent each of sodium and ammonium nitrates and maintained saturated with carbon dioxide. C. D. 15 amperes per square foot anode surface; temperature 16° C. Carbon dioxide continuously injected and water added as required.

442,661. December 16, 1890. Turner D. Bottome, Hoosick, N. Y.

Desilverizes lead with production of white lead. The argentiferous lead anodes are immersed in solution composed of 3 per cent each ammonium nitrate and carbonate, carbon dioxide being continuously injected. The lead is said to be precipitated as basic carbonate, while the silver is deposited in metallic state on the cathode.

459,946. September 22, 1891. David V. Kyte, Indianapolis, Ind.

Argentiferous lead anodes are immersed in a solution of an acid capable of forming a soluble salt, preferably 300 cc of pure nitric acid to two liters water, but mentions also as suitable acetic, hydrochloric, sulphuric, carbonic, oxalic, tartaric and citric acids. Passes current (10 amperes per square foot anode surface) until solution is saturated with lead, then substitutes carbon anode and silver cathode and precipitates silver as metal. Removes electrodes, carefully neutralizes solution by sodium or potassium hydrate and injects carbon dioxide to precipitate white lead; or may neutralize solution by alkali metal carbonates. Claims larger yield by reason of the slight solubility of the basic salt in the neutral electrolyte.

496,109. April 25, 1893. Arthur B. Browne, Cambridge, Mass.

Pig lead anodes supported on a grid, electrical contact being made through a skeleton frame of aluminium. Cathode is lead-faced wooden block supported above anodes. Sodium nitrate or acetate is introduced below anodes. Anode and cathode products react to form hydrated oxide of lead, which is transformed into carbonate by being permitted to dry in air or in atmosphere of carbon dioxide.

527,830. October 23, 1894. Arthur B. Browne, Cambridge, Mass.

White lead produced by process of United States patent 496,109, has a yellow tinge, which is attributed to organic matter aided by mordanting action of aluminates formed at cathode. To obviate color subjects the lead hydrate to the action of an alkali carbonate solution while the former is still moist, thereby dissolving out coloring matter and partially carbonating. The hydrate thus purified is washed and carbonated as in 496,109.

551,361. December 17, 1895, and 555,232, February 25, 1896. Arthur B. Browne, Cambridge, and Edwin D. Chaplin, Natick, Mass.

Apparatus and process respectively for continuous production of white lead. A series of electrolytic cells, each provided with lead anodes and any insoluble conductors as cathodes is employed. A solution of sodium nitrate as electrolyte flows through like compartments of all cells in succession. Anode and cathode solutions are mixed in separate vessels, the precipitated lead hydroxide filtered off and converted into carbonate by sodium carbonate. Resulting white lead separated by filtration and dried.

560,518. May 19, 1896 Jules Meyrueis, Paris, France.

Caustic soda from electrolytic cell is admitted to boiler containing litharge; the hot solution is drawn off and carbonated to precipitate white lead. Resultant alkaline solution withdrawn and further carbonated to form sodium bicarbonate, the mother liquor being returned to the electrolytic cell.

563,553. July 7, 1896. Arthur B. Browne, Cambridge, and Edwin D. Chaplin, Natick, Mass.

Substantially the same process as United States patent 555,232, excepting that two pervious diaphragms are employed and the electrolyte is introduced between them; a somewhat higher solution level is maintained between the diaphragm to prevent diffusion. Instead of a lead anode a carbon anode may be used, the lead to be dissolved being placed adjacent thereto. Nitric acid is added either continuously or at intervals to dissolve crystals of basic lead nitrite, which tend to form in anode compartment.

563,554. July 7, 1896. Arthur B. Brown, Cambridge, and Edwin D. Chaplin, Natick, Mass.

Caustic soda solution electrolyzed with lead anode in positive compartment of a cell provided with a diaphragm, thereby forming brown oxide of lead, which is dissolved in caustic soda. The resulting plumbate is neutralized by carbon dioxide precipitating white lead. The caustic soda and carbon dioxide are derived from the cathode and anode compartments, respectively, of an electrolytic cell supplied with a solution of sodium carbonate.

563,555. July 7, 1896. Arthur B. Browne, Boston, Mass.

Improvement on 563,553. Finds that if electrolyte between diaphragms be maintained by circulation below a certain degree of alkalinity diffusion of hydrate into positive compartment is prevented and no necessity arises for adding an oxidizing agent. This specification states the equations in accordance with which the production of white lead is presumed to take place.

The balance of this class of patents will be dealt with in our next issue.

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## NIAGARA FALLS MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY

The fourth general meeting of the American Electrochemical Society, a full report of which is found in this issue, again scored a full success, and will be remembered by all who attended it as a highly profitable and enjoyable affair. True, both the attendance and the number of papers fell short of the figures reached in the last two meetings, but this was only what was to be expected. The first three meetings, at Philadelphia, Niagara Falls and New York City, represented a series of successes, each greater than the former, so that some moderation in the pace was inevitable. The fact that this only manifested itself in a quantitative but not in qualitative respect, speaks very well for this youngest of the technical societies of this country. Good will and good feeling all around were the keynote of the social features of the meeting, and that the numerous workers in the art and science of electrochemistry who only two years ago were absolutely scattered, and without any connecting link, are now firmly bound together in professional solidarity is probably the most important broad result to be credited to the society.

While the slight decrease in the number of papers presented to the society will somewhat curtail the thickness of the printed volume of the Transactions, yet the members who attended the sessions were, perhaps, pleased that the technical programme was not overcrowded to the same degree as at the last two meetings, and that there was thus allowed time for thorough discussion of the papers presented. An important feature was the comparatively large number of papers on practical subjects, and it is noteworthy that some of the best papers of this class came from American universities.

An excellent example of what scientific investigations in our universities can do for the progress of industry was Dr Bancroft's paper. We do not think its intrinsic value is to be found entirely in the three suggestions formulated at the end of the paper, but rather in the exact and systematic method of determining accurate numerical data on the mutual relation between current density, temperature, and power consumption in copper refining. The tables of cost and the conclusions reached as to the conditions under which the cost becomes a minimum, are of value as showing how to apply the results of systematic scientific work to certain given conditions of practice. Dr. Bancroft has clearly stated the conditions for which his results are true, and has given both the items of cost which he has taken into account and those which he has not. Every copper refinery knows exactly all the conditions under which it is working, and is now able to determine the most economical current density and temperature for its own case on the basis of Dr Bancroft's experiments. Of special interest is Dr Bancroft's recommendation as to covered tanks, which did not

meet with the approval of several prominent practical refiners who joined in the discussion. But this question, as Dr. Bancroft remarked, is one that should be considered purely a question of cost. He gives the data, showing how many dollars and cents can be saved in power by the introduction of covered tanks, and the question to determine is whether this saving in cost is counterbalanced by increase in cost in other directions. If we consider the high degree of perfection of the mechanical features of our modern refineries, we should think that a convenient method of mounting the covers, and one which would allow an easy inspection of the tanks, is not impracticable.

Prof. Brown's paper on the nickel deposition also was of great interest. We have frequently urged in this journal that electroplaters should endeavor to know what is going on in their cells, and that in order to get good results they should not only consider the cathodic deposit, but the actions in the cell as a whole. The fundamental point which decides the success of any electrolytic process, namely, that the initial conditions should, so far as possible, be maintained during the entire process of electrolysis, requires in the case of the plating bath that the anodic corrosion shall correspond to the cathodic deposit. The ideal method of ascertaining whether this is the case is naturally Prof. Brown's method of measuring the anodic potential against a standard electrode; but human inertia is also a law of nature, and it seems too extravagant a hope to entertain that the average electroplater will readily be brought to measure electrode potentials in this manner. However, the test suggested at the end of Prof. Brown's paper appears to be a good substitute, and requires little apparatus. At least a good voltmeter should certainly be in the hands of every electroplater.

Prof. Burgess' paper on an electrolytic method of removing brass from iron is a very pretty example, showing how well-known old facts which are apparently only of theoretical interest may be used in actual practice. On Dr. Walker's paper on the cathodic reduction of gold ores we comment in another editorial note. From Mr. Salom's paper it appears that while the chemistry of his lead reduction process has not been changed, yet his new cell involves a great improvement in mechanical features. Mr. Hambuechen's paper related to an interesting cell which, by means of an aluminium electrode used as an electrolytic valve, acts at the same time as a rectifying and as an electrolytic cell. Finally, Dr. Byrnes' paper was a very welcome contribution to the extremely important question how to construct a good diaphragm for certain classes of electrolytic work.

While most of the practical papers thus concerned some phase of electrolytic work, there were two interesting papers on the subject of electric furnaces. Mr. FitzGerald gave some general rules for the design of resistance furnaces, and Mr. Ruthenburg recorded the latest advances of his promising electric iron process. Of the papers on theoretical problems, that of Mr. Moltkehansen was an interesting example of the application of electric methods to the decision of doubtful chemical problems. The paper of Dr. Richards and Mr. Landis was of special interest on account of the apparently bold suggestion of a method of measuring electric conductivities of solutions by a direct-current method. Mr. Lidbury's paper proved again how dangerous it is to make generalizations based merely on some similarity between different classes of phenomena; his very interesting results on the electrolysis of water vapor, due to electric spark discharges, should call the attention of more experimenters to this important field. The general discussion of the electrolytic dissociation theory was rather tame, in view of the savage opinions held by some on one side or the other of this polemical question. Two points brought out in this discusion were of special interest. First, Dr. Bancroft's claim that the experimental investigations of the past are not sufficient to establish the molecular weights in solutions as abnormal, and that accurate investigations on this fundamental question are under way. Second, Dr. Richards' interesting paper on the thermochemistry of the dissociation theory, with his peculiar method of calculating the neutralization heat. We hope to return to this subject in a later issue.

## THE GENERATION OF ACETYLENE

The future of the calcium carbide industry depends essentially on the progress of the use of acetylene for lighting, and consequently the problem of generating acetylene from calcium carbide and water is one of prime importance. At first sight the problem is an extremely simple one. Whenever calcium carbide is brought into contact with water, the generation of acetylene results. That this apparent simplicity has been an enormous incentive for inventors, seems to be indicated by the fact that there have been granted about 1000 United States patents for acetylene generators. On the other hand, promoters were equally attracted, and in Europe, wherever there was a small water-power, it was considered as a suitable place for erecting a calcium carbide plant. The large European manufacturers of electrical apparatus fostered this ultra-rapid development, interested, however, rather in the sale of electrical machinery than in the permanency of the calcium carbide business. Overproduction and a general commercial crash in the European calcium carbide industry was the natural result.

We may point with some pride to the fact that in this country of "unlimited possibilities," the calcium carbide industry has developed along conservative lines, has shown a slow but steady growth, and gives every promise of continuing to develop along the same lines. This is essentially due to two reasons: First, the calcium carbide industry is in this country in the hands of a single large and responsible company—which example indicates that monopoly may at times be a very useful thing for all concerned; and, second, the careful examination of acetylene apparatus by a committee of the National Board of Fire Underwriters, which has issued a "list of permitted machines." It is now clearly understood that the problem of the generation of acetylene from calcium carbide and water is a chemical problem, and that the designer of an acetylene apparatus must not only possess mechanical skill, but a knowledge of the chemistry of the subject.

We are glad to call the attention of our readers to an article contributed to our present issue by Mr. J. M. Morehead, who, as the chemist of the Union Carbide Co., speaks

with authority on this subject. Electrochemical methods may be considered generally as a means for storing energy in form of a chemical compound; and, in fact, this is the only effective means, known up to the present, for storing energy. The energy of the falls of Niagara, after conversion into electrical energy, is stored in form of chemical energy in calcium carbide. We get the energy back when we change calcium carbide into acetylene and use acetylene for lighting. When acetylene is used for illumination somewhere in the West, we have a case of chemical transmission of energy from Niagara to the West. Calcium carbide is an exceedingly active chemical substance, which property gives it its commercial value, but, as Mr. Morehead points out, this same property has to be reckoned with in obtaining the maximum degree of satisfaction and safety in its use. A careful and scientific study of the physical chemistry of the process of generating acetylene has led to the understanding of three possible sources of danger; danger from overheating, from excessive after-generation, and from an explosure of a mixture of gas and air. Mr. Morehead's discussion of these three points, and of the means by which danger has been eliminated in the modern design of acetylene generators, is very lucid, and should appeal, not only to chemists, but to the large class of progressive engineers in several fields who may have to consider the installation of acetylene generators, but are not yet convinced of their practical safety. As such progressive engineers are largely represented in the subscription list of this journal, we hope that Mr. Morehead's article will do some good. There can be no doubt that in great sections of this country where electric light installations would not pay, acetylene will be the illuminant of the future, and is entitled to this role by the excellence of its light per se.

## THE PRECIPITATION OF GOLD FROM CYANIDE SOLUTIONS.

In this issue we publish an interesting paper on the precipitation of gold from cyanide solutions by Messrs. W. A. Caldecott and E. H. Johnson. The long activity of the authors in the classical country of cyanide processes—in South Africa—gives special weight to their exposition of the problem which is not only of the greatest commercial importance, but also of much scientific interest on account of the complex, and not yet fully understood chemical reactions involved in this process. Practically we distinguish between the precipitation of the gold by means of the electric current, as in the Siemens & Halske process, and the so-called chemical method of precipitation by means of zinc shavings or zinc dust. But from the facts recorded by Messrs. Caldecott and Johnson one might conclude that this latter "purely chemical" method is also essentially an electrochemical process. The authors record the fact that the precipitating efficiency of chemically pure zinc is almost nil, impurities in the zinc being essential. This fact would lead to the hypothesis that when we use zinc shavings we have short-circuited galvanic cells, the pure zinc and the impurities acting as electrodes respectively.

However, the electric precipitation of gold from a cyanide solution upon the cathode is not a very simple affair. We know that gold is not the cation of the double salt of gold and potassium, but that it represents a part of the anion radicle, which, under the directive force of the current, moves away from the cathode. Potassium is the cation and is primarily deposited on the cathode, and the cathodic deposition of gold which we observe is only the result of a secondary reaction between the primarily deposited potassium and the double salt in solution. This explains why thorough agitation of the solution is an essential element of success.

In this connection we may refer to a method of precipitation of gold from certain telluride ores, described by Dr. W. H. Walker in an American Electrochemical Society paper, read at Niagara Falls and abstracted on another page of this issue. Dr. Walker found that with the special type of ore with which he experimented, the gold deposit on the cathode was due to direct cathodic reduction rather than to a previous anodic solution and following cathodic deposition. Dr. Walker's method is therefore essentially different from the Siemens & Halske process. While the latter may be compared in some respects with the process of copper refining, involving first solution and afterwards precipitation, Dr. Walker's method is analogous to the Salom process of cathodic reduction of galena to lead.

## ELECTROLYTIC PRODUCTION OF DYES AND PIGMENTS.

Aside from the electrolytic production of white lead, the discussion of patents relating to which is completed in the digest of the present issue, the United States patents cover a variety of dyes and pigments produced by electrolytic methods. The organic dyes are but scantily represented, the patents being confined to a few simple reduction and oxidation methods. In the production of pigments, however, we find a considerable number of variations of a single principle. In general, a soluble anode is dissolved in a suitable electrolyte, and the desired compound of the anode metal is precipitated, either by the hydroxide, which is simultaneously produced at the cathode, or by a suitable precipitant added to the electrolyte. Thus, for instance, hydrated copper oxide is produced by solution of a copper anode in sodium chloride solution and subsequent reaction with the caustic soda from the cathode; basic phosphate of copper is produced by the electrolytic solution of copper anodes in chlorate solutions to which soluble phosphates are added; lead chromate results from the passage of the current from a lead anode through an electrolyte consisting of soluble chlorates and chromates, etc.

Whatever advantage this method is presumed to possess over direct precipitation of the compound from mixed solutions obtained by ordinary chemical methods must be based upon the assumption that the current efficiency is substantially perfect; otherwise very serious difficulties arise, because the current losses will be found to correspond quite closely to changes undergone by the electrolyte and such changes mean in general, not only a variable product but an excess of acid or alkali, the effect of which is to introduce very serious disturbances. Such effect seems moreover to be cumulative, so that variations from the theoretical efficiency which might appear at first sight to be negligible may have a serious bearing upon the question of practicability. The value of such methods is only to be determined after long-continued trials.

## METALLURGY AND CHEMISTRY IN SOUTH AFRICA

The Chemical, Metallurgical and Mining Society of South Africa held its general meeting on July 18, in Johannesburg. The proceedings of the meeting are recorded in the July number of the journal of the society.

Mr. S. H. Pearce, in his presidential address, referred to the beginning of the society, when it was nicknamed the Cyanide Club; "considering the vast improvements made in the cyanide process, mainly by efforts of the members of the society, it is a matter rather to be proud of than otherwise." He referred to the many possibilities which have sprung up since the late war, and expressed the hope that South Africa will soon respond to the attack that combined capital and labor are making upon its resources, and will become not only self-supporting, but take that prominent part in contributing to the world's supply of metals, minerals and even foodstuffs, that it does now in the supply of gold and diamonds.

After some remarks on mining problems which have sprung up, Mr. Pearce remarked that if one looks up the metallurgy of gold, one finds that in the early days of Australia the first mining was limited to washing up alluvial ground; later it was found payable to hand-crush the richer quartz and pick out the nuggets, long before the introduction of stamp mills and amalgamation. So it is in South Africa; so long as there is so much apparent profit in it, gold mining will remain the staple industry; but now the country is being thoroughly prospected, and it will not be long before those deposits, which are at present only indicated, will be definitely located, and the production of other metals become an accomplished fact. Large deposits of iron ore, of a higher class than many being worked in Europe or America, are known, and in some cases in proximity to coal, clay, lime, etc. Copper, zinc, nickel, lead, silver, tin and antimony are known to exist in varying quantities, as also are oil shale areas, while the coal deposits, if not always of a very high quality, appear to be unlimited, and will possibly be supplying the world when all others are exhausted.

South Africa, Mr. Pearce says, is backward in the chemical field. There is at Modderfontein a dynamite factory, one of the finest of its class, and there is also a chemical works, whose chief product is sulphuric acid, but beyond this, chemical industries are practically wanting. In agricultural chemistry very little has been accomplished; hygienic chemistry is another subject practically untouched.

"Analytical chemistry is a matter that more directly concerns us, and in this matter, including, as it does, the assaying of ores, tailings, and residues, etc., I should like to bring to your notice and consideration the plan of standardizing methods of analysis, as in America, by means of commissions appointed to determine those which are best and most suitable, these being subsequently adopted as standard methods throughout the country. If we take as an example our methods of assaying and sampling, the matter will appeal to most of you. Comparisons are always odious, but we have got into the habit of making them frequently in the matter of extractions, and as there is probably no other place where minute accuracy is of the same importance as it is in this matter, I have no hesitation in stating that up to the present we have still much to do before our comparisons are justly based. There is no reason why we should not appoint our own commissions and show that we can also evolve standard methods here just as we have been able to pioneer the way in the cyanide process of gold extraction."

Mr. W. Cullen remarked that while South Africa metallurgy in the past has been exclusively gold, yet he does not think that it will be very long before they have one or two other metals, such as lead and zinc, to deal with.

Mr. H. S. Denny read a paper with the title "Observations on the Metallurgical Practice of the Witwatersrand." An abstract of this paper, which was characterized by the president as "the most interesting paper ever read before the society," will be published in our next issue. The following papers were read by title: "An Automatic Pulp Sampler," by James Higham; "The Ventilation of Deep Levels," by Thomas Johnson; "The Precipitation of Gold from Cyanide Solutions," by W. A. Caldecott and E. H. Johnson. The last paper is published, nearly in full, elsewhere in this issue.

## MINERAL RESOURCES OF CUBA.

From the recently published annual report of the United States Consul-General at Habana for 1903 we gather the following information concerning the mineral resources of Cuba.

There is not at present sufficient knowledge regarding the real mineral richness of the island to form an exact opinion or to make an accurate estimate of the same. In former times, the mines were profitably worked. The industry afterwards was totally stopped, owing to the abnormal circumstances in which the island remained during many years. The benefits of peace are giving new vigor to this enterprise, judging from the great number of petitions for concessions filed in the offices of the civil governors of provinces.

The mineral resources of the island are represented by the following products: Gold, silver, iron, copper, manganese, lead, asphalt, petroleum, naphtha, graphite, amianthus, zinc, mercury, and, it is stated, coal. These minerals are found in most of the provinces, but the richest mineral district is the province of Santiago de Cuba, followed in importance by Santa Clara, Puerto Principe, Pinar del Rio, Matanzas and Habana. The following statement of the existing mining concessions in the different provinces will give an idea of the importance of the mineral interests of the island, and the list will be increased when exact and complete statistical data can be obtained:

| Province | Mines Number. | Area. Acres. |
|---|---|---|
| Santiago de Cuba | 386 | 44,586 |
| Santa Clara | 59 | 4,288 |
| Puerto Principe | 27 | 5,202 |
| Pinar del Rio | 13 | 1,361 |
| Matanzas | 11 | 444 |
| Habana | 10 | 514 |
| Total | 506 | 56,395 |

Of this number of mines, very few of iron, manganese, and copper in the province of Santiago de Cuba are in operation. The others can be considered only as concessions waiting for funds for exploitation. The administration, according to the laws in force, can not compel the miners to operate their claims. The owner is in possession of his mine to perpetuity, and at his own will may work it or not. The only cause of forfeiture established by the law is the failure to pay the annual taxes.

The taxes to be paid to the government are $5 yearly per hectare (2.471 acres), or $30 for each claim containing 6 hectares (14.8 acres), when the mines are of precious stones or metalliferous substances.

In the other cases, the tax is $2 per hectare (2.471 acres).

## THE NATIONAL BUREAU OF STANDARDS.

From a recently published report of the National Bureau of Standards, of which Dr. Stratton is president, it appears that the departments dealing with electricity, thermometry and pyrometry, are already in working condition. At present there are facilities in the electrical department for the comparison of resistances covering a wide range, and for the calibration of direct-current ammeters up to 600 amperes, direct-current voltmeters up to 300 volts and of direct wattmeters. The equipment of the alternating department is not yet complete. The department of thermometry is equipped with the necessary apparatus for measuring temperatures in the intervals from 0° to 100° C., with the highest attainable accuracy. For work between 100° and 550° C. apparatus is now under construction, and for the testing of pyrometers in the interval between 500° and 1500° C., much of the necessary apparatus is already in hand.

## THE GENERATION OF ACETYLENE.

By J. M. Morehead.

Calcium carbide is an exceedingly active chemical substance. It possesses chemical and physical properties which give it its commercial value, but which at the same time have to be reckoned with to obtain the maximum degree of satisfaction and safety in its use. Carbide will evolve acetylene through the simple contact with water, but, on the other hand, it will continue to evolve acetylene as long as there is carbide in contact with water, and if confined the pressure will rise beyond the pressure necessary to liquify the gas, which is at ordinary temperature 750 pounds to the square inch, and the heat of compression and of generation will rise to a point higher than the dissociation temperature of the liquified acetylene. Acetylene will give from ten to twelve times the light of ordinary gas for the same volume, but at the same time, it possesses more than twice the heat units of the best water gas, and when mixed with just the proper proportion of air and ignited it, like water gas, will dissociate with explosive violence, the energy of the explosion being in proportion to the heat unit content.

When it is considered that the only thing necessary for the production of acetylene is the simple contact of calcium carbide and water, and that the necessary and inevitable result is the immediate evolution of quantities of acetylene varying only in direct proportion with the quantity and purity of the two bodies concerned in the reaction, it would seem that very little scope was afforded to the mechanical ingenuity of the inventor in devising means by which the necessary contact between the two interacted bodies can be brought about; but a glance through the patent files of the last five years, through the advertising columns of the trade journals or the list of over one hundred generators—all different—which have been passed by the various boards of underwriters will prove that such is by no means the case.

Unfortunately a number of designers of acetylene apparatus, while undoubtedly possessed of a high degree of ingenuity and mechanical skill, had but little idea and less definite knowledge of the properties of one of the bodies with which they were dealing, and as a result many generators were arranged with very little regard to safety, and while they did generate acetylene, they made the gas in anything but its purest form, and many gave a far smaller yield of gas of probably a lower candle power per unit of carbide consumed than could be gotten from the same carbide by some machine else constructed upon more rational principles. The weak points in the early designs soon made themselves evident by leaks, by unsatisfactory light, by high cost for light and, in some instances, by explosions.

As the different defects became known, they were corrected in the succeeding machines, and with the growth of the business, the smaller and more irresponsible manufacturers have been crowded out, until now, with the ninety-three thousand machines in actual operation, operated for the most part by people with a minimum of mechanical ability, and an absolute ignorance of gasmaking, an accident is of exceedingly rare occurrence, and in almost every case where one does occur, is directly traceable to the needless ignorance or to the gross carelessness of the person having the generator in charge.

A great part of the progress towards safety in the design and construction of acetylene apparatus has been due to the thorough and intelligent supervision given to all appliances by the underwriters board of engineers. This board inspect and test all apparatus with a view always first to safety, and then to efficiency and to economy, and until the apparatus has received their sanction, it is not allowed in insured buildings.

The three points most to be considered are danger from overheating, danger from excessive after-generation, and danger from an explosion of a mixture of gas and air.

So far as the toxic properties of the gas are concerned, they may be considered as practically zero. If nothing but acetylene was breathed for a sufficient time, death from asphyxiation would ensue just as would be the case if nothing but hydrogen or nitrogen or carbonic acid or steam were breathed, but in so far as being poisonous, that is in being able to arrest the processes of animal life, like cyanogen or the carbonic oxide contained in water gas and coal gas, is concerned, acetylene may be considered as absolutely safe.

Grehant reports that in his laboratory a dog breathed a mixture containing 20 per cent acetylene and 80 per cent of air for thirty-five minutes without showing signs of distress, while another dog breathing a similar mixture of coal gas and air containing only 1 per cent of carbon monoxide, quickly showed convulsive movements and died after ten minutes. An ordinary sized bedroom, say 12 x 12 x 12 feet, contains 1728 cubic feet. Twenty per cent of this is 345.6 cubic feet. It would require the largest acetylene burner 346.6 hours, or 14.33 days to produce a 20 per cent mixture in this room, and the ordinary sized burner twice as long, and this is upon the assumption that there is absolutely no ventilation.

When we consider the strong odor which acetylene possesses and which would give immediate warning of a leak, we may dismiss the fear of any danger of asphyxiation connected with acetylene, and if our cousin from the country prefers to blow out the gas, let him, it will do no harm.

### Overheating.

When calcium carbide is brought into contact with water, a certain definite amount of heat is generated from the reaction of their mutual decomposition, and of the attendant subsequent slaking of the lime, which is produced as a by-product and left as a residue. There is no way of avoiding the production of this heat. It is in obedience to a law of nature. The ability to, and the necessity of, producing heat when brought into contact with water is one of the physical properties of calcium carbide just as weight, color or crystalline structure is. It cannot be avoided and so must be provided for. This heat amounts to 414.6 calories per gram of pure carbide, or one pound of pure carbide develops, when acted upon by water, sufficient heat to raise the temperature of 80.4 gallons of water, one degree F., or the temperature of one gallon of water 80.4° F. Or the heat, liberated by the evolution of gas from one pound of pure carbide and from the subsequent slaking of the lime forming the residue—provided that none of the heat were wasted—is sufficient to raise the temperature of 0.49 gallon of water from the freezing point to the boiling point.

The first consideration in the design of an acetylene generator is means of getting rid of this heat. At a temperature of 536° F., or about half the temperature of dull redness, acetylene polymerizes and changes in the chemical structure of the acetylene begin to take place, and the degree of success attained in keeping the temperature below the above point determines in a very large measure the success or failure of the machine.

There are two ways of getting rid of this heat of generation:

First, by dissipation into the surrounding air, and second, by absorption in water.

Dry machines depend upon the first principal. Wet machines upon the second. A few small machines bicycle and automobile lamps, etc., depend upon the first principle. All large machines upon the second. The underwriters require dissipation for one gallon of water for every pound of carbide, and as it requires only 0.56 of a pound or a little over one-half pint of water for the chemical reaction, the possibility of danger, or rather of annoyance from overheating, may be considered as out of the question with any approved acetylene generator now on the market.

### Overgeneration.

As mentioned above, if care is taken and everything worked just exactly wrong calcium carbide and water are capable of

producing excessive pressure, but the present generators retain their gas by means of water seals, which would "blow" at a few pounds and relieve the pressure. They are all—with one exception—made of galvanized iron, which would rupture before a dangerous pressure was reached, and, too, the board of underwriters require that all approved machines be provided with automatic blow-offs, piped to the outside air. These blow-offs open automatically for either excess volume in the holder, or excess pressure any place in the system.

As acetylene is non-explosive up to very high pressure, this possible source of danger may be considered as provided for and safe-guarded.

### Explosion of Mixture of Acetylene and Air.

A gas explosion is not, properly speaking, an explosion. It is really a very rapid and a very violent burning. A true explosion is a dissociation, a tearing apart, while a so-called gas explosion is the result of a combination. A true explosion, which results from the ignition of nitro-glycerine, gunpowder and the other nitrate explosives, gives rise to permanent gases which occupy vastly more space than did the original solid or liquid body concerned in the reaction. A cubic foot of gunpowder without any admixture of air or anything else, if heated to 400° F. will dissociate according to the formula,

$$2KNO_3 + S + 3C = K_2S + 3CO_2 + N_2$$

into permanent gases, which, when cold, will occupy 280 cubic feet. The temperature attained at the instant of dissociation is 2100 to 2200° F., and as gases double in volume for an increase of 492° F. in temperature, gunpowder may be said to produce at the instant of explosion about 1200 its volume of gas.

A cubic foot of nitroglycerine, if heated to 350° F., dissociates according to the formula,

$$4C_3H_5N_3O_9 = 12CO_2 + 10H_2O + 6N_2 + O_2$$

into permanent gases, which, when cold will occupy 748 cubic feet. The temperature in this instance would be 4500° F., and the total volume of gas at the instant of explosion would be 6748 cubic feet, or as many times the volume of the original explosive.

As compared with these, acetylene at anything less than several hundred pounds pressure is not of itself explosive. It can be polymerized or caused to combine with itself, but no amount of heat or of concussion will cause it to dissociate into its elements. To get any explosive effects, acetylene must be mixed with just the right amount of air. The maximum explosive effect is obtained by mixing the gas with two and a half times its volume of oxygen or 12.5 times its volume of air. A mixture of acetylene and oxygen requires a temperature of 512° F. to ignite it when it combines according to the formula,

$$C_2H_2 + 5O = 2CO_2 + H_2O.$$

If mixed with 12.5 parts of air instead of with pure oxygen, the reaction is the same, except for the pressure of nitrogen on both sides of the equation. The nitrogen is not changed, but serves to raise the ignition temperature from 512° to 900° F. The temperature of combination of acetylene and 12.5 per cent of air, due to the fact that acetylene is an endothermic body is high, reaching the temperature of 4100° F.

One volume of acetylene and 2½ of oxygen give rise to only two volumes of a permanent gas, or one cubic foot of the explosive mixture produces .59 cubic feet of gas against 280 and 748 for gunpowder and nitroglycerine, respectively. The energy of a gas explosion is due to the sudden heating of the gases produced, and of the nitrogen carried by the air. This 2.86 volume of inert nitrogen to every one volume of active acetylene and oxygen in the mixture has a very great retarding effect upon the reaction, and hence the energy of the explosion is far less than would appear from a consideration of the temperature attained or which would be the case with pure acetylene and oxygen.

In a gas explosion, two things are essential. First, a mixture of gas and air in proper proportions. Second, the mixture must be ignited. There are two ways of avoiding an explosive mixture. First, not to supply sufficient air for combustion, and, second, to dilute the gas with air beyond the explosive point. Mixtures within these limits will combine with explosive violence if ignited. The explosive limits of the more common gases are as follows, the percentages are by volumes.

| | Start | | Maximum Explosibility | | Stop | |
|---|---|---|---|---|---|---|
| | Gas | Air | Gas | Air | Gas | Air |
| | Per cent | | Per cent | | Per cent | |
| Acetylene | 3.1 | 96.1 | 12.5 | 87.5 | 24.1 | 75.9 |
| 24 C. P. water gas | 7.8 | 92.2 | 17.0 | 83.0 | 2.3 | 77.0 |
| Pintsch gas | 4.8 | 95.2 | 9.0 | 91.0 | 11.0 | 89.0 |
| Natural | 6.5 | 93.5 | 11.0 | 89.0 | 11.8 | 88.2 |

It will be noted that the limits for acetylene are wider than are those for the other gases. This is explained by the superior gravity of acetylene. There is more carbon and hydrogen, more substance, more *gas* in a cubic foot of acetylene than there is the other gases. This will be seen by an inspection of the following table of specific gravities:

| | Gravity. |
|---|---|
| Air | 1.00 |
| Acetylene | 0.92 |
| 24 C. P. water gas | 0.64 |
| Pintsch gas | 0.73 |
| Natural gas | 0.56 |

The chances of getting a mixture of acetylene and air which will be within the explosive limits are less with this gas than with other gases. Taking the same bedroom mentioned above, the largest burner would have to be left open for almost eight days before a mixture of maximum explosibility would be obtained, and it would be over three days before the mixture could be lighted. This assumes also that there is absolutely no ventilation. Another point which makes for the safety of acetylene is the limited quantity available. So rich is the gas that the ordinary generator does not hold more carbide than sufficient to make about fifty feet of gas, and in case of a broken pipe or fitting, this is the maximum amount to be had. Having obtained the mixture which is within the explosive limits, it is still necessary to ignite it. There are two ways of doing this.

First, by heat of generation inside of the generator, and, second, by heat or flame from outside.

While it is a chemical possibility to obtain sufficient heat to ignite acetylene by slowly and continuously adding water to a large excess of carbide, the modern machines, which drop a limited quantity of carbide at a time into a large excess of water, have almost entirely eliminated this possibility of danger.

The generators now upon the market are designed so that the residue may be removed and the stock of carbide replenished with the minimum escape of air into the machine or of gas into the room. A simple system of interlocking valves prevents the opening of the carbide chamber before all gas valves are closed. If operated according to instruction, no feature of the operation or care of an acetylene generator, as at present supplied, possesses any of the elements of danger. Acetylene, like any gas which will burn, will explode if mixed with air. Cubic foot for cubic foot, it covers a little wider range and is slightly more explosive than other gases. Candle-power for candle-power, other illuminating gases are from five to twelve times as explosive as is acetylene. A leak of acetylene is no more apt to occur than is a leak of any other gas under similar conditions.

An acetylene generator can, through gross ignorance or carelessness, be made to fill a basement with gas just as it can by only ordinary care be made to supply a system of burners. A

basement full of air and gas, water gas, coal gas, natural gas, or acetylene gas, is harmless unless ignited. If the basement is entered with a candle or with a lighted match, or the mixture is ignited from some external source, the results are practically identical, without regard to the nature of the gas supplying the active element.

# FOURTH GENERAL MEETING OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

The fourth general meeting of the American Electrochemical Society was held at Niagara Falls from September 17 to 19. The number of members and guests registered was 138, a complete alphabetical list being given at the end of this report. While the attendance was less than at the two last meetings, all those who were present concurred in the sentiment that the meeting as a whole was a very enjoyable electrochemical "family affair;" there was good will and good feeling all around.

Much credit for this success is due to the efforts of the local committee. While its chairman, Mr. E. G. Acheson, was prevented by sickness from being present, the other members of the committee, and notably its indefatigable secretary, Mr. Clarence L. Collins, 2d, were restless in their endeavors to extend courtesies and to make everybody feel at home. The smoker on the evening of September 17 and the reception and dance on the evening of September 18 were well attended by the members and guests with their ladies, and were greatly enjoyed. On the afternoon of September 19 a delightful excursion was made by trolley and boat to Fort Niagara. In the afternoon of September 17 and 18 various plants were visited, which will be referred to at the end of this report. The mornings were taken up by sessions devoted to the reading and discussion of papers. The intention was to read all papers relating to electric furnaces on Thursday, all papers relating to electrolysis on Friday, and to devote the Saturday session to a general discussion of the electrolytic dissociation theory. In general, this programme was adhered to. In the following we give the papers and discussions in abstract.

## Thursday Session.

At the beginning of this session the secretary, Mr. C. J. Reed, and the treasurer, Mr. Pedro G. Salom, presented their reports. The membership list has passed the 600 mark and the treasury has a surplus of $2,000. Arrangements have been completed to exchange publications with the recently founded Faraday Society of England, so that each member of the American Electrochemical Society and of the Faraday Society receives both the Transactions of the former and the organ of the latter (The Electrochemist and Metallurgist) free of charge. The foundation of local sections is approaching realization; Prof. Burgess announced that the members of Madison, Wis., are about to start a local section. Other local sections will probably be founded in the near future in New York and in Philadelphia.

### Note on Some Theoretical Considerations in the Construction of Resistance Furnaces.

The first paper was presented by Mr Francis A. J. FitzGerald, on the above subject. He divided electric-resistance furnaces into two classes: First, those furnaces in which the current passes through the whole charge, and second, those in which the current passes along a definite path or paths, thus localizing the heat. The author then discussed the furnace invented by E. G. Acheson, according to this classification.

The furnace for making graphite electrodes belongs to the first class, but is peculiar in that the heat is mainly generated outside of the articles under treatment. The electrodes to be converted into graphite are arranged in piles, and the spaces between the latter are filled with granular carbon.

Since the resistivity of the granular carbon mass is much greater than that of the electrodes, most of the heat is developed in the former. The advantage of this type of furnace is that it permits of treating a large mass of low-resistance material without using currents of excessive amperage. (See Electrochemical Industry, October, 1902, p. 53.)

As examples of the second class of furnace in which the current passes along a definite path only, the carborundum and the "white stuff" furnaces are mentioned. In the carborundum furnace the charge consisting of sand and coke in the form of powder, is placed in a box-like furnace, and through its center passes the conducting core of granular carbon or a carbon rod, connecting the terminals of the furnace. The current is confined to the core, raising it to a high temperature, and the heat generated is conducted into the surrounding mixture, converting it into carborundum. Careful temperature regulation is necessary, because if the temperature becomes too high, the carborundum is decomposed and the silicon is vaporized (See Electrochemical Industry, October, 1902, p. 50.)

The "white stuff" furnace is of the same general form as the carborundum furnace, but has to produce only a moderately high temperature. As "white stuff" is an intermediate product in the formation of carborundum, and the temperatures between which it is formed and decomposed apparently lie near one another, the problem of its design is difficult and was solved by Acheson by the use of several cores, "definitely spaced with relation to each other at distances largely determined by the heat conductivity of the charge, the duration of the operation and the superior and inferior temperature limits of the operation." (See Electrochemical Industry, May, 1903, p. 332.)

The highest temperature is produced in the furnace for converting carbon in a bulk into graphite. The carbonaceous material, anthracite coal, coke, etc., is placed in a trough-like furnace, and through the centre of the charge is a series of carbon rods connecting the furnace terminals. Anthracite coal, the raw material usually employed, is practically a non-conductor of electricity, and first the current passes through the carbon rods, so that at the beginning of the operation the furnace belongs to the second class of resistance furnaces. But gradually the heat generated in the core converts the surrounding coal into graphite, which then becomes a conductor and heats another layer of coal, and so on till the process is complete. At the end of the operation the furnace therefore belongs to the first class of furnaces of the resistance type.

In all these furnaces the electric resistance is a variable quantity, and after a furnace is started there are no means of adjusting internal conditions so as to effect regulation in this respect. In general the resistance of the furnace is high at the beginning of a run and low at the end; therefore means of varying the voltage at the furnace terminals must be used. If the highest and lowest available voltage and the maximum available watts are given quantities, then by a simple application of Joule's law we can find the limits between which the resistance varies. The resistance may be varied by alternating

the dimensions of the core, and by judiciously choosing different forms of carbon, which have different resistances. (The case of the graphite electrode furnace is a special one, the adjusting of the resistance being obtained, to a certain extent, by the spacing between the piles of electrodes.)

The author then gives the equations for the passage of heat from a cylinder (the core of the furnace) through a heat conducting material (the charge) under certain special conditions which are only approximately fulfilled in a commercial electric resistance furnace. He then applies his formulas to the different Acheson furnaces.

With regard to the Acheson furnace for converting coal in bulk into graphite, the author shows that his formulas limit the size of the furnace in order to get high efficiency. For the carborundum furnace he arrives at the conclusion that the heat conductivity of the material around the core should be as great as possible; this can be best accomplished by having the mixture surrounding the core of high density, for then the crystal mass formed will also be dense.

While his equations involve numerous assumptions which do not represent the conditions and take no account of certain factors, the author points out that keeping the theoretical considerations in view is a great help in the building of furnaces, and prevents waste of time in experimenting with designs that cannot possibly be satisfactory.

In the discussion Dr. J. W. Richards asked what was the power factor in furnace operation; Mr. FitzGerald replied that in commercial furnaces the power factor is not unity; in fact, it was rather low in the early types of furnaces, owing to considerable self-induction due to the construction of the electric leads; but this disadvantage was partly overcome by means of interlaced bus-bars. Mr. A. H. Cowles referred to experiments made by him in 1885 in which he produced carborundum and some material apparently similar to what is now called "white stuff;" Dr. Mabery had analysed this material and believed to have found a sub-oxide of silicon. Mr. FitzGerald replied that he had made many analyses, but could not find any evidence of a sub-oxide of silicon. (See concerning this point an interesting communication by Mr. FitzGerald, published in the correspondence column of this issue.)

Mr. Carl Hering said that the formulas given in the paper would be considerably more valuable if numerical values were given for the constants entering into these formulas. Mr. FitzGerald replied that this was impossible, as his formulas were not intended to be considered as exact, but only to serve as a general guide; they should not be applied to numerical calculations.

Mr. Cowles doubted that in the carborundum furnace the current passes only through the core, and referred to the fact of a decrease of voltage at the end of a furnace run. Mr. FitzGerald replied that carborundum is practically a non-conductor of electricity, and that the crystals are so arranged as not to offer a very good continuous path for the electric current; he thinks the fact that the voltage drops at the end of a run is due to the conversion of the original carbon core into graphite, which is a much better electrical conductor. Mr. Cowles then described an experiment made by him in which during a run the carbon core (which had been suitably arranged for this purpose) was removed; the current was found to drop off one-third; he therefore concludes that hot carborundum is a conductor of electricity. Mr. FitzGerald remarked he had never read any description of this experiment; he thinks that carborundum is practically a non-conductor compared with carborundum. Prof. C. F. Burgess said that experiments in this direction had led him to the same conclusion.

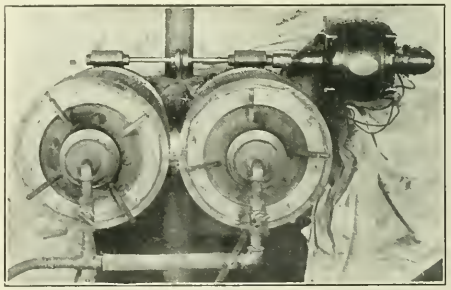
Dr. Richards asked whether any calculations of the efficiency of the furnace have been made by Mr. FitzGerald. The latter assured that he had commenced such calculations, but on account of the many doubtful "constants" which enter into the problem, he gave it up as a bad job.

### Advance in Electrometallurgy of Iron Production.

A short paper with this title was presented by Mr. Marcus Ruthenburg, who referred to his paper of last year (Electrochemical Industry, November, 1902, p. 84), and reported advances made in his process since that time. He agrees that the blast furnace is a highly economical device for accomplishing its end, and will continue to be so until methods be found that will perform its functions for less money.

For certain cases, however, the blast furnace is unsuitable. For instance, given a magnetic ore-carrying gangue, with sulphur and phosphorous in prohibitive quantity for making good steel economically, such ores find no market tributary to the blast furnace. On the other hand, such ores may be crushed, magnetically concentrated, electrically smelted and produce the best of steel at a price which can compete with an ideally situated blast furnace. For this purpose the Ruthenburg process is intended to be used.

The crushed ore, having been magnetically concentrated, drops into a magnetic zone between two revolving cylinders, where it forms a bridge, due to the action of the magnetic field, and is electrically melted; it then becomes unmagnetic and drops down into the soaking pit. New material forms then a bridge and so on. (For further details see Electrochemical Industry, February, 1903, p. 202, also the description of the Ruthenburg plant at the end of this report.) The



Ruthenburg Furnace, Front View,
Showing the Water-Cooled Magnetic Poles and the Bridge of Ore, Being Smelted.

action of the electric current is only to melt the dusty particles, to agglomerate them into coherent masses without binder or flux, and to convey a sufficient quantity of heat to the ore in the soaking pit. The reduction takes place in the soaking pit through which heated hydrocarbon gases or CO are passed.

Three problems were to be solved in the evolution of this process; first, the electric power required to agglomerate and sufficiently heat the material for subsequent reduction; second, the regulation of the size of the agglomerated particles; and third, the amount of reduction of the agglomerated material. The status of the solution of these three problems is given by Mr. Ruthenburg as follows:

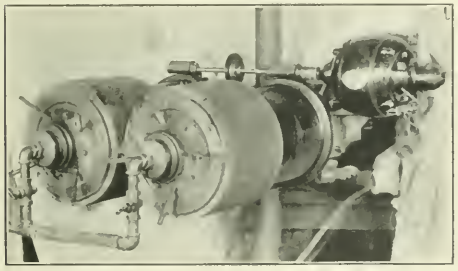
First, a ton of ore is being agglomerated with an expenditure of about 250 kw.-hours (against 500 kw.-hours last year, this improvement being due to the use of the new apparatus). Second, the size of the product is under perfect control. Third, the reduction is being made absolute.

In the discussion which followed, Mr. C. J. Reed asked as to the efficiency of the process. Mr. Ruthenburg replied he had made no such calculations; all he does as a practical engineer is to weigh his ore, to analyse it before and after treatment, and to measure the consumption of energy by means of a recording wattmeter. Mr. Cowles, however, gave figures of the thermochemistry of the process.

Dr. G. P. Scholl asked as to the analysis of the material; Mr. Ruthenburg replied that phosphorus is removed by the preliminary magnetic separation; if, however, any phosphorus should get into the electric furnace, it would not be eliminated; on the other hand, he is convinced that sulphur is absolutely eliminated, due to the reaction between $Fe_3O_4$ and $FeS_2$ at the high temperature (about 1200°) in the melting zone of the electric furnace.

Mr. Beckett questioned the possibility of a complete removal of sulphur; he had made a series of experiments in the same line, but was unable to get iron free from sulphur; he also referred to the impossibility to solve the analogous problem to get metallic nickel by the reaction of nickel oxide and sulphuric sulphide. Mr. Ruthenburg replied that in his experiments he had found the amount of sulphur in the final product to be very small. Dr. Richards said that magnetic ore is in itself low in sulphur.

Mr. Cowles pointed out that the only material which drops into the soaking pit is iron oxide after having been fused; when it is accumulated in the pit, it represents a heated mass in a retort, through which the heated hydrocarbon gases are passed to produce the reduction; the material in the soaking pit is at the right temperature required for reduction. Mr. Ruthenburg called attention to the fact that iron is peculiar, in so far as the reduction of iron oxide by CO takes place at a comparatively low temperature, somewhat above that of boiling water; this is the temperature in his soaking pit. He considers



SIDE VIEW OF RUTHENBURG FURNACE.
The Small Motor at the Right Hand is Used for Revolving the Two Rolls in the Front.

this as one of the principal points in which he saves energy, compared with other electric steel processes, because, in his process, the heat and current losses due to maintaining a molten mass are lacking.

President Richards, in concluding the discussion, referred in some complimentary words to Mr. Ruthenburg as one of the successful pioneers in a new field of electrometallurgy in this country. He expressed his belief that when electric steel processes will once become industrial processes, they will become the largest electrochemical industry.

### An Electrolytic Process of Removing Brass from Steel.

Prof. Charles F. Burgess presented a paper on "a practical utilization of the passive state of iron." It has long been that iron or steel, when used as anode in a solution of sodium nitrate or of various other soluble nitrates, soon assume what is called the passive state, i. e., they are no longer attacked by the anode products, and behave just like a platinum anode, oxygen gas being liberated. The passive state thus produced is probably the same condition which iron assumes when immersed in concentrated nitric acid. The author describes a process in which this passive state is made use of in an industrial way.

An improvement in the method of brazing employed extensively in the manufacture of bicycles consists in dipping bodily a portion of the frame to be brazed into a bath of melted spelter, which is covered by a suitable flux. By this operation not only is the brazing effected within the joints, but a thin layer of brass adheres to the outer walls of the tubing, so that it becomes necessary to remove this layer in preparing the frames for receiving a coating of enamel. To effect this by filing, entails a large amount of labor and frequently the thin tubing is damaged, as some of the iron is removed as well as the brass.

In experiments made by the author, it was tried to find an electrolytic process by which the brass could be removed electrolytically from the iron; but with a great many electrolytes, tried at first, the iron tended to corrode much more readily than did the copper which enters into the constitution of the brazing smelter. The reason is that iron has a position considerably above copper in the electrochemical series of elements, and where two different metals are in contact, the natural tendency is for the more electropositive one to go into solution with the greater ease.

The solution of the problem was that by using a sodium nitrate solution, iron is made to assume the passive state, its position in the electrochemical series of elements is changed, it becomes more electronegative than copper. With such a solution it was found that the brass could be completely removed and the iron left intact. This method of electrolytic stripping was installed and operated with success in various factories, and is now an important adjunct to the dip-brazing method. This same electrolytic stripping process may be applied equally well in removing silver, lead, tin and other metals more electronegative than iron from an iron surface. Nickel cannot be removed in this way, however, since nickel, as well as iron, assumes the electronegative or passive state.

The author then gave some measurements of the single potential of iron in a normal sodium nitrate solution, determined against the Ostwald calomel standard electrode, the potential of which was taken as —0.56 volt. The single potential of iron in $NaNO_3$, before any current is passed through the iron as anode, is in the neighborhood of +0.2 volt; in other words, a potential is set up towards the solution in the same direction, but of less magnitude than would be produced by zinc. By causing the current to pass from the iron as anode, however, this potential quickly becomes negative, and increases rapidly in negative value, until a potential as high as —2.0 volts can be obtained under certain condition. A sudden and considerable increase of the potential takes place at the moment when the iron assumes the passive state. This occurs with greater rapidity, and at a much lower current density, if some $NaNO_2$ is added to the $NaNO_3$ solution. This fact explains why the iron does not assume the passive condition when used in sodium nitrate solution freshly prepared, but only after the current has passed for some time; at the cathode sodium is liberated which unites with the water to form sodiumhydroxide, and the hydrogen thereby set free reduces the sodium nitrate to nitrite.

On the other hand, copper, when used as anode in sodium nitrate, does not change its potential in anywhere near the same degree, so that the iron may readily be made much more electronegative than copper. If an iron and brass plate are exposed simultaneously to the solution as anodes, each plate being connected through an ammeter to the same source of current, on closing the circuit almost all of the current passes through the iron anode, but after operating for a few seconds the iron becomes passive, after which the brass takes all of the current. By using very high current densities, however, the iron may begin to conduct a small portion of the current, thus causing a liberation of oxygen on its surface.

In the discussion Mr. C. J. Reed referred to a case in which lead is changed to lead peroxide and then acts like platinum, evolving oxygen at its surface, and asked whether Prof. Burgess would call this the "passive state of lead." Prof. Burgess replied that the behavior is quite similar in both cases, but he would apparently not commit himself to a direct statement

that it is a coating of iron oxide which produces the passive state of iron, as this is a disputed question.

### Friday's Session.

#### An Experiment on the Electrolytic Determination of the Basicity of Acids.

A paper on this subject was presented by Mr. Ivar Juel Moltkehansen. He referred to the fact that measurements of the electrolytic conductivity in connection with Ostwald's dilution law have been successfully used to reach a decision in cases in which complex acids of doubtful basicity were in question. He has used this method in the study of the constitution of the metaphosphoric acids.

The question of the constitution of the different metaphosphoric acids can only be solved by analysis of their double salts, as the determination of their vapor density is not practicable, owing to the decomposition of the metaphosphate vapors, even at a low pressure. The metaphosphates are dissociated in a water solution, and their molecular weight cannot, for this reason, be determined by the methods of lowering of the freezing point or the increase of the boiling point. They are not soluble in solvents containing no hydroxyl, such as benzol or chloroform. A decision as to the constitution of the water—soluble metaphosphates is, however, possible according to their conductivity for the electric current.

The author investigated Glatzel's and Fleitmann's dimetaphosphoric ammonium, by examining its equivalent conductivity in suitable dilutions and applying the formula given by Ostwald. The measurements were made by the method of Kohlrausch with the Wheatstone bridge connections and telephone. His measurements show the acid to be dimetaphosphoric acid in the ammonium salt, with two molecules of water of crystallization. On the other hand, Warschauer has arrived by similar measurements at the conclusion that Fleitmann's dimetaphosphoric acid does not exist, but that the acid described as such by Fleitmann and Glatzel is tetrametaphosphoric acid. Further investigations are necessary to explain this discrepancy.

#### Electrometallurgy of Gold.

A paper on this subject was presented by Dr. W. H. Walker. The electrometallurgy of gold is based on the facts that the electric current may be used to advantage both for dissolving metallic gold in a cyanide solution in form of the double salt $AuKCy_2$, and for depositing it from such a solution. The effect of the current in the process of dissolving appears to be that it supplies oxygen, for it has long been known that the process of dissolving Au in an aqueous solution of K Cy requires the presence of oxygen. On the other hand laboratory experiments have shown that in a $KAuCy_2$ solution the cation is K and the anion is $AuCy_2$; this is of great importance for the process of precipitating the gold from the solution. What is primarily precipitated, is the cation K, which then acts on the $KAuCy_2$ solution with the resulting secondary precipitation of gold. The gold is, therefore, contained in the anions which travel away from the cathode so that the current tends to impoverish the solution in gold near the cathode. On the other hand, it is just at the cathode where the gold is wanted, in order to enable the secondary reaction between the primarily deposited potassium and the $KAuCy_2$ to take place. This shows the importance of stirring and agitation for the process of precipitation, and it also explains why the efficiency will be small.

The author then gave a review of the electrochemical gold processes and divided them into two classes. The first class comprises those processes in which the solution and precipitation do not take place simultaneously. The Siemens & Halske process belongs to this class; it is used on a large scale in South Africa. The ore is first leached out in the leaching plant, and is then supplied to the precipitating tanks; the older and newer arrangements of the electrodes were described. The main advantage claimed for the electrochemical precipitation of gold over the chemical method by means of zinc shavings, is that the former requires less concentrated solutions and the consumption of cyanide is smaller.

The second class of processes comprises those in which the solution and precipitation takes place simultaneously. The author described and discussed the following three processes: Pélatan-Clerici, Riecken, and "Aurex-Sluice." The reason why these processes have failed on an industrial scale seems to be that great quantities of ore are required to recover a small quantity of gold, and that these great quantities of ore must be continually moved.

The author finally gave an account of some experiments made by him on the cathodic reduction of gold telluride. The results prove that the electrolytic processes working on this class of ore recover their values in greater part by cathodic reduction than they do by first dissolving the mineral in the anode liquor with the subsequent precipitation of the gold on the cathode. Good contact with the cathode is therefore the essential requirement, and this was not appreciated by the first experimenters. This is an example showing why some processes may be successful in the laboratory and later fail on a commercial scale.

In the discussion of the paper Dr. Bancroft referred to a published statement that the Siemens & Halske people in South Africa do not use the Siemens & Halske process, but have bought the Andreoli patents and work under the same; Andreoli uses lead peroxide anodes and iron or aluminium cathodes. Dr. Richards referred to experiments made by him to determine the efficiency of the Siemens & Halske process on a laboratory scale; the best results gave an efficiency as low as $\frac{1}{4}$ per cent; he pointed out, however, that in the economical production of gold the cost of power for electrolysis, and, therefore, the efficiency of the electrolytic process does not cut any figure whatever.

#### Electrolytic Copper Refining.

Prof. Wilder D. Bancroft presented a paper in which he gave an account of a series of experiments made under his direction in Cornell University by Messrs. Schwab and Baum. The first object of the investigation was to determine the most economical current density and temperature for the process of copper refining. With increasing current density the cost of power necessary for precipitating a given weight of copper increases, while the interest charge on the copper in the tank decreases. Good adherent copper can be obtained at almost any current density, provided the rate of circulation be sufficient. With rising temperature the cost of power decreases, while the cost of heating the tanks increases.

To strike a balance between these conflicting factors, the relation between voltage, current density and temperature for pure copper plates, set a definite distance apart, was determined in four solutions of compositions used in practice. By expressing the voltages in terms of the voltage at 20°, the effect of the distance between the plates was eliminated, and the percentage variations hold for any set of plates in the same solutions.

Data were also obtained showing the relations between current efficiency, current density and temperature for pure copper plates in the same four solutions. Finally the variation of the cost with varying conditions of temperature and current density were determined for the case of all power costing at the rate of $20 per horse-power-year, and also for the case in which steam heating costs only one-thirtieth of electrical heating.

The object of the first test were to determine the variation of voltage with variation of temperature current density and solution. The following four solutions were used: first, 16 per cent $CuSO_4 \cdot 5H_2O$ and 9 per cent $H_2SO_4$ (commercial solution used in refineries with multiple system); second, the same with a small addition of NaCl (1÷2,000,000 of solution);

third, 16 per cent $CuSO_4$, $5H_2O$, and 6 per cent $H_2SO_4$ (commercial solution used in refineries with the series system); fourth, the same with a small addition of NaCl. The experiments were made on a small experimental scale, beakers being used, instead of tanks.

The results were given by Dr. Bancroft in a series of tables for temperatures between 20 and 90° C., and current densities between 1 and 4 amperes per square decimeter. The voltage required to obtain a given current density is materially less with the 9 per cent acid solution than with the 6 per cent acid solution. The addition of sodium chloride to the solution increases the voltage at the lower temperatures, while the effect is scarcely noticeable at the higher temperatures.

The object of a second test was to determine the variations of the ampere-hour efficiency when operating with the same four different electrolytic solutions at varying temperatures and different current densities. It was found that the ampere-hour efficiencies for temperatures below 70° C. fall off but very little, and are practically 100 per cent. Even at a temperature of 90° C. and the nigh current density of 4 amperes per square decimeter the efficiency runs as high as 98 per cent and 99 per cent for the 9 per cent and 6 per cent solutions, respectively, while a current density of 1 ampere per square decimeter gives an efficiency of 90 per cent and 91 per cent. Between 50° and 70° the efficiency in some cases runs a trifle above 100 per cent, due to the formation of cuprous sulphate in small quantities in the electrolyte. (Foerster and Seidel found that the current efficiency drops off rapidly above 50° C., but they used very low current densities, 1 ampere per square decimeter being their highest density.)

The deterioration of solution is proportional to the ratio of anode loss to cathode gain, since pure copper plates were used and there was a sediment or copper scrap on the bottom of the beakers. The solution deteriorates more rapidly at the higher temperatures and at the lower current densities. This deterioration of solution probably more than offsets the advantage of decrease in voltage which the higher temperatures give, but only when operating at the lower current densities. The ratio of anode loss to cathode gain, when operating at 70° C. and 4 amperes per square decimeter, is hardly any higher than this ratio for operating temperatures between 20° and 50°.

The author gives in a series of tables the watt-hours per gram of copper for the different solutions under different conditions, also the ratio of the watt-hours at higher temperatures to those at 20°, and the ratio of the corresponding voltages. As an example we give the results for the 9 per cent acid solution without NaCl, for current densities of 3 and 4 amperes per square decimeter:

| | Ratio of voltage to that at 20°. | Ratio of watt-hours to those at 20°. |
|---|---|---|
| 20° C. 3 amp. per sq. dm. ..... | 1.000 | 1.000 |
| 50° C. 3 " " ..... | 0.600 | 0.600 |
| 70° C. 3 " " ..... | 0.441 | 0.440 |
| 90° C. 3 " " ..... | 0.347 | 0.354 |
| 20° C. 4 " " ..... | 1.000 | 1.000 |
| 50° C. 4 " " ..... | 0.605 | 0.605 |
| 70° C. 4 " " ..... | 0.454 | 0.454 |
| 90° C. 4 " " ..... | 0.362 | 0.368 |

In a special test with solutions containing iron, no falling off in the current efficiency could be found.

An important part of the investigation was the radiation run, made to form some idea of the relative costs of operating at various temperatures, with covered and uncovered tanks. The temperature of the electrolyte in a covered tank decreased from 96.1° to 44° C. in 123 minutes; in the same tank, uncovered, from 94.5° to 44.7° in 60 minutes. The power in watts required to overcome the radiation of heat and keep the temperature unchanged, is given in the following table:

| | 90 | 80 | 70 | 60 | 50 degs. C. |
|---|---|---|---|---|---|
| Covered tank .. | 44.0 | 36.6 | 28.8 | 21.7 | 14.5 watts |
| Uncovered tank. | 145.0 | 90.4 | 50.6 | 34.4 | 20.6 watts |

These figures refer to the small tanks used in the experiments. To get the watts for commercial tanks of 9 x 2 x 2½ feet, as used in the Baltimore refinery, the figures in the table are to be multiplied by 100.

In a further test an attempt was made to duplicate commercial conditions in the precipitation of electrolytic copper. Finally the data obtained in all of these tests were used by Dr. Bancroft to calculate the cost of refining. The basis of this calculation was: Dimensions of tank, 2 x 2½ x 9 feet; one tank containing 130 electrodes of two plates each; weight of copper per tank = 5,700 pounds; value of copper per tank = $800, cost of power = $20 per horse-power-year; plant temperature = 20° C. The calculation is on the basis that the heating of the electrolyte is done by means of the electric current and that the ampere-hour efficiency is 100 per cent.

The following three items of cost were taken into consideration: Cost of kilowatt-hours required to precipitate one tank of copper; cost of heat required to keep the temperature of the electrolyte constant; interest on the copper in one tank at 6 per cent. The sum of these three items is called "total cost" and is given in dollars in the following table, which is only an extract from that given in Dr. Bancroft's paper.

Cost per Tank of Copper.

| Amperes per sq. dm. | At 50° C. | At 70° C. | At 90° C. |
|---|---|---|---|
| 2.0 | $2.70 | $3.87 | $5.09 |
| 3.0 | 2.58 | 2.57 | 3.39 |
| 4.0 | 2.72 | 2.33 | 2.54 |

As stated before, these figures give the cost per tank of copper. The following table gives the corresponding figures per ton of copper:

Cost per Ton of Copper.

| Amperes per sq. dm. | At 50° C. | At 70° C. | At 90° C. |
|---|---|---|---|
| 2.0 | $0.95 | $1.36 | $1.79 |
| 3.0 | 0.91 | 0.90 | 1.19 |
| 4.0 | 0.95 | 0.82 | 0.89 |

While these figures are based on experiments with the series system, it is probable that the conclusions to be drawn would apply equally well to the multiple system. The kilowatt-hours per kilogram of copper will be larger in a multiple tank, owing to the greater distance between plates. The radiation losses are probably also greater, owing to the tanks being relatively wider. Otherwise there is little difference, since the extra interest charge in the multiple system, owing to the use of thick anodes, is offset by the possibility of removing the cathodes before the end of the run, which cannot be done in the series system.

As in practice the solutions are heated by steam coils, and as this costs less than electric heating, the following table gives the results calculated on the basis of electric power at $20 per horse-power-year, and steam heating at one thirtieth the price of electric heating:

Cost per Ton of Copper.

| Amperes per sq. dm. | At 50° C. | At 70° C. | At 90° C. |
|---|---|---|---|
| 2 | $0.91 | $0.83 | $0.80 |
| 3 | 0.91 | 0.78 | 0.72 |
| 4 | 0.95 | 0.82 | 0.89 |

The commercial cost per ton of copper will be between the figures given in the last two tables, which are, therefore, to be considered as limits. These figures of cost comprise only the three items stated above. They do not include the cost of labor and are based on the assumption of 100 per cent ampere-hour efficiency. Since the number of men employed does not vary with the current density, the cost of labor per ton of copper will be less, the higher the current density. The correction for the actual current efficiency is easy to apply when one has the data and will not affect the general results, because the current efficiency is practically independent of the temperature and current density at temperatures below 90°

and within the range of current density considered. The question of the deterioration of the electrolyte need not be considered, because the amount of deterioration is also practically independent of the temperature and current density at temperatures below 90°.

To apply these results to the commercial problem of copper refining, two sets of curves were plotted, one showing the relation between the cost of precipitating a ton of copper and the operating temperature, the second set showing the relation between the cost of precipitating a ton of copper and the operating current density. From these curves the conclusion was drawn that the results at 70° C. seem the most satisfactory with a current density of 3.5 and 3.75 amperes per square decimeter. Under these conditions no extra power would be required to heat the solution. Operating at this current density *with covered tanks,* the current alone would be sufficient to heat the electrolyte to over 80° C. In order to secure good circulation, essential for a good deposit with high current densities, the method of pumping could be retained. If the gutters leading to and from the pump were properly insulated, the solution would not drop below 70° C. before returning to the tanks. Moreover, running at this high current density, there would be a considerable saving in the first cost of the plant, inasmuch as fewer tanks are needed for the precipitation of a given amount of copper in a given time.

The lower the cost of heating, the greater the advantage of a high temperature. Lowering the rate of interest decreases the advantage of a high current density. With covered tanks, it will be possible for men to work in the tank room even with the electrolyte at 70°.

If the cost of working under so-called standard conditions for open tanks, i. e., a current density of 14 amperes per square foot, and a temperature of 50°, is compared with the cost of working with covered tanks at 70° and a current density of 3.5 amperes per square decimeter (31.5 amperes per square foot), the saving by the latter method will be very close to $1.00 per ton of refined copper when all power is figured at $20 per horse-power-year.

Therefore, in order to operate a plant most economically, Dr. Bancroft concludes, copper should be refined electrolytically under these conditions: Covered tanks; current density 3.5 amperes per square decimeter; temperature 70° C.

In the discussion which followed Dr. Bancroft's paper, Dr. Richards read three communicated discussions by Mr. Benjamin Magnus, superintendent of the Anaconda refinery, Mr. Lawrence Addicks, electrochemist of the Raritan Copper Works, and Prof. T. R. Rosebrugh.

Mr. Benjamin Magnus stated his experience had been that the ampere-hour efficiency depends entirely on mechanical conditions. If a tank is kept free of most local short circuits, one may very easily attain a desirable maximum ampere-hour efficiency in practical refining. By "desirable maximum efficiency" he means an efficiency which can be obtained by an expenditure of labor which costs less than the gain to be gotten by a higher efficiency. Where the general efficiency is 95 per cent he had succeeded in getting it up to 97.5 per cent, but the extra labor was not saved by the extra saving in power.

Concerning the statement of Dr. Bancroft that the solution deteriorates more rapidly at the higher temperatures, and at the lower current densities, Mr. Magnus stated he had found this true for high temperatures, but not for low current densities. At the Anaconda plant, where a low current density is used, they have been able to use the same electrolyte continuously for many years; but at other plants, where the current density is 60 per cent higher than at Anaconda, they found it necessary to renew some part of their electrolyte frequently. At low current densities the oxidation of impurities occurs quite freely, thus keeping the electrolyte from becoming fouled with impurities.

Mr. Magnus then criticised Dr. Bancroft's statement that since the number of men employed does not vary with the current density, the cost of labor per ton of copper will be less the higher the current density. In actual practice this is not the case. High current densities cut down the interest on copper tied up and the interest on investment for plant, etc. But, as a matter of fact, the plants having high current densities usually have higher labor costs per ton of copper produced than plants using low current densities. Mr. Magnus referred to two well-known plants which use respectively 10.5 and 40.0 amperes per square foot, the one with the higher current density having a labor cost 40 per cent greater than the plant using the lower current density. Concerning the proposal of covered tanks Mr. Magnus said that only a casual inspection of a tank room in any practical plant would soon convince a visitor of the objection to covering tanks.

Mr. Magnus finally discussed, by way of demonstration, the conditions at the Anaconda refinery. The current density is 10.5 amperes per square foot, the temperature of the electrolyte is 100° F. and the circulation of the electrolyte is 3 gallons per minute. Under these conditions the chemical action in the tank is 1 per cent greater than the electrolytic action, and the voltage per tank is 0.23 volt. In order to keep the solution constant day by day, the extra copper taken up by the solution, due to the 1 per cent greater chemical action, is taken out by means of a tank which has insoluble anodes. The cost of operating this tank is at least eight times the cost of operating a regular depositing tank, the voltage being 2 in the former. Most electrolytic plants use exhaust steam for heating the electrolyte, but even if they used live steam, which costs $80 per horse-power-year, the cost of heating the electrolyte per ton of copper produced would only be from 16 to 35 cents; and if they raised the temperature of their solution to 70° C. and raised the current density to 31.5 amperes, the excess chemical action would be so great that to free the electrolyte from copper, by means of tanks having insoluble anodes, would cost so much that the saving of power due to warmer solutions would be more than offset.

Mr. Lawrence Addicks said that electrolytic refining from a standpoint of economy consists of a very nice balance of a number of conditions, and that while Dr. Bancroft has considered some he has in turn overlooked others which cause him to arrive at what, in the mind of Mr. Addicks, are erroneous conclusions. While it is true that good adherent copper can be obtained at almost any current density, provided the rate of circulation be sufficient, yet we are limited in circulation to a very small rate; otherwise we have a turbid solution and a cathode which is not only impure, but carries a prohibitive amount of silver. A system where a torrent of circulation carries all slimes rapidly out of the tank to be settled or filtered out in the dump might avoid this, but there is no such system in use, and the conclusions reached in the paper are applied to existing plants. Insufficient circulation at once means poor deposition and necessitates frequent renewal of the cathode sheets to maintain the current efficiency and entails a corresponding increase in labor lost. Take the Anaconda and Great Falls plants for example: the former, with a density of 11 amperes per square foot, draws copper every 35 days; the latter, with 40 amperes, every two days. Less than four times the density and but a seventeenth of the age. While Dr. Bancroft did not claim to consider labor cost, yet Mr. Addicks thought we must consider labor cost to make any such sweeping statements as those at the end of the paper.

Mr. Addicks said that Bancroft's work on temperature coefficients was more complete than any he had seen elsewhere, and very interesting, but that the idea of covered tanks would be greeted with much hesitation by most refiners. It is hard enough to get thorough inspection on with an open tank, let alone a closed one. With very high temperatures they would undoubtedly be warranted, as otherwise the vapor in the air would make work unbearable. Their application to a series tank would be much simpler than to a multiple one with its external connections. Mr. Addicks expressed the opinion that

if interest and depreciation on the plant were considered in Bancroft's cost tables, the changes would revolutionize them.

Mr. Addicks concluded that current density and temperature of electrolyte bear vital relations to the cost of refining; while Dr. Bancroft has furnished some valuable data, and for some refinery his conslusions are true, yet against their application to every plant that can obtain power for $20 a horse-power-year, he would protest.

Prof. T. R. Rosebrugh criticised the cost of $20 per electric horse-power-year, and the assumption that the cost of steam heating is one-thirtieth of electric heating.

Mr. Woolsey McA. Johnson referred to some similar experiments made by him some time ago on nickel refining; he had also plotted similar curves, but he emphasized that the results of such curves must be translated freely into practice. He criticised a statement of Dr. Bancroft concerning the observation that during the last commercial test the voltage across the terminals of the tank rose from 1.75 volts at the beginning of the run, to 2.10 volts three and a half days later, which was attributed by Dr. Bancroft to the deterioration of the solution, i. e., to the neutralization of the acid. Mr. Johnson thought there were two other reasons for this rise of voltage, the increased resistance of the slimes and the concentration changes in the slimes.

Dr. Bancroft, in his reply, first referred to the criticism of Prof. Rosebrugh and stated that his assumption of $20 per electric horse-power-year was simply taken as a standard; if at any other place the cost is different, then one can easily make the calculation. His assumption concerning steam heating is to be considered only as a limit. Concerning the rise of voltage, he said that Mr. Johnson's criticism was disproved by the experiment, because the voltage assumed again its original value when the electrolyte was restored to its original condition; of course, in the nickel refining process from which Mr. Johnson had derived his argument, the conditions may be different. Replying to Mr. Magnus and Mr. Addicks he said that his experiments showed no greater deterioration to take place at 70° C. than at lower temperatures. He expressed his belief that the objections raised against covered tanks were greatly overstated; it is not difficult to arrange the covers so that they may be easily lifted, and if this is done, the only difference with present practice will be the slight extra time necessary to swing or lift the covers. On the other hand every refiner should carefully consider that covered tanks may mean a saving of 30 per cent of power, even under the present conditions of current density and temperature.

Concerning the criticisms that in his cost tables he had overlooked important factors, Dr. Bancroft said that he had clearly stated all factors which he had considered and those which not; on the basis of his experimental results every refiner is now enabled to make the calculation of the most economical current density and temperature for his own refinery, using his own figures.

### Corrosion of the Nickel Anode in Nickel Plating.

A paper on this subject was presented by Prof. Oliver W. Brown. In the absence of the author it was read by Mr. W. McA. Johnson. The author pointed out that a plating bath must be considered as a whole; while a good cathodic deposit is the goal to strive at, it is necessary to also consider carefully the condition of the anode. To get high efficiency it is necessary that the anode shall corrode at the same rate as the nickel is deposited on the cathode.

If this would be the case, the e. m. f. at the terminals of the cell would be only necessary to overcome the resistance. In reality there is, however, a counter e. m. f. of polarization at the anode. To study this problem in detail, the author measured the single anodic potential (against an Ostwald calomel standard electrode, the potential of which is taken as —0.56 volt) and used various kinds of nickel for the anode. Some of the most important results are given in the adjoining table, 0.45 ampere hour being used in all cases.

| Nickel Anode | Amperes per Square Foot | | Discharge Potential in Volts | | Current Efficiency | |
|---|---|---|---|---|---|---|
| | Anode | Cathode | Anode | Cathode | Corrosion of Anode | Dep. of Nickel on Cathode |
| Cast, surface ground smooth | 4.42 | 2.21 | —1.881 | +0.208 | 46.298 | 75.42 |
| Cast, surface roughened in acid | 4.42 | 2.21 | —0.44 | 0.252 | 91.32 | 92.06 |
| Rolled, pure | 4.42 | 4.42 | —1.889 | 0.145 | 8.47 | 63.27 |
| Electrolytic | 4.42 | 4.42 | —1.883 | 0.148 | 12.65 | 61.61 |

The results show that electrolytic nickel anodes corrode very poorly, as compared with cast anodes; also that pure rolled anodes are no better than the electrolytic. The different efficiencies obtained with cast anodes of smooth and rough surface are of interest. The cathode efficiency is affected to a marked degree by the anode efficiency. From further experiments it seems that the highest cathode efficiency is obtained when the cathode discharge potential lies between +0.22 and +0.29 volt. The anode voltage increases very fast as the anode efficiency begins to diminish. It appears that an efficiency of corrosion exceeding 90 per cent cannot be expected if the anode voltage is allowed to get much above —0.46 volt.

The author concludes that the satisfactory operation of a nickel-plating solution depends to a large extent on the character of the anode employed. This is a fact which has been recognized by platers as a result of practical operation. It might be a natural supposition that the best results should be expected with the purest anode material, but this apparently is not the case. It appears that the presence of copper is advantageous to a certain extent, and it is quite likely that certain other impurities which are usually present in cast nickel may be equally advantageous. It has been shown that rolled nickel or electrolytic nickel are decidedly unsatisfactory for anode service, and the reason that the cast nickel shows a superiority may be due to the impurities or to a different physical structure, which gives rise to a great porosity and roughness of the surface, and thereby a greater actual surface area.

In electroplating operations the cathode has naturally been the point to which most attention has been given in the production of certain qualities of deposit, but a study of the conditions at the anode is equally important, for if the corrosion at that point is satisfactory the cathode will largely take care of itself. The lack of efficient corrosion at the anode results in an excess of acid being formed, which, diffusing to the cathode, causes a lower efficiency at that point as well. A change of efficiency at the anode is in a very short time made apparent by a similar change at the cathode. In instructions which have been published from time to time for operating nickel-plating tanks, the voltage which is necessary for plating is referred to in an indefinite way. This is probably due to the fact that the e. m. f. required under different conditions is of a considerably different value, so that no definite rules can be laid down. The electroplater can obtain an efficiency of 90 per cent or more if cast anodes are used, with an anode density of about 5 amperes per square foot. The best method of obtaining a check on his efficiency is by the determination of the anode discharge potential. This should not be allowed to reach a greater value than —0.45 volt (measured by the Ostwald standard electrode).

The Ostwald standard electrode might be considered too much of a scientific piece of apparatus. The measurement of the polarization of the cell, while much simpler, is not as definite in its indications as the measurement of the individual potential of each anode and cathode separately.

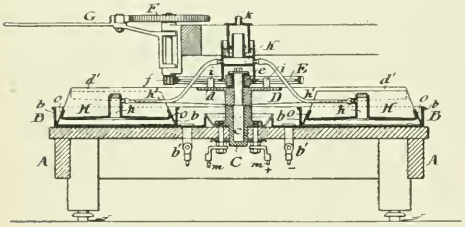
Nevertheless the simple measurement by means of a volt meter, of the counter e. m. f. of polarization in the cell, will serve as a general means for determining whether the cell is operating properly. When the polarization goes much above 0.75 volt, the assumption is justified that the anode is not corroding properly, and on the other hand, if the polari

ization is below 0.70 volt the efficiency at the anode is as high as can be obtained. The means for measuring this polarization is at the disposal of most electroplaters, the method consisting in connecting a voltmeter to the anode and cathode terminals while the current is flowing, and then suddenly interrupting the current and noting the pressure between the electrodes immediately after. This reading should be taken as quickly as possible, as the polarization decreases rapidly after interrupting the current.

In the discussion which followed, Mr. Woolsey McA. Johnson spoke highly of the paper and recommended the study of the anodic and cathodic potentials against a standard electrode as one of the best means of ascertaining what is going on in an electrolytic cell. He thought that the method might be too complicated and expensive for the average electroplater, a good potentiometer costing about $150. But the simple measurement of the total polarization, recommended by Brown at the end of his paper, might be a good substitute, and would require no special instruments nor scientfic training. He criticised Brown's paper in so far as not enough analyses had been made.

Prof. Burgess said that the Ostwald standard electrode is a very handy instrument; it is simply constructed, and he has found it to be of the greatest use in his laboratory; the potentiometer arrangement used by Brown was a home-made affair, and costs less than one-tenth the amount mentioned by Mr. Johnson.

Dr. J. W. Richards referred to the statement in Brown's



SALOM ELECTROLYTIC CELL.

paper that some impurities in the anode seem to have a good effect on the corrosion of the nickel; he thought this might be explained by assuming local action, the pure nickel and the impurities, in contact with each other, acting as anode and cathode respectively in a short-circuited cell. Dr. R. Gahl objected to this explanation on account of the overvoltage on nickel; this remark precipitated some discussion between Messrs. Reed, Richards and Gahl on the subject of overvoltage.

### A New Type of Electrolytic Cell.

A paper on this subject was presented by Mr. Pedro G. Salom. His new type of cell, while applicable to other electrolytic processes, is mainly intended to be used in connection with his electrolytic process of reducing galena to spongy lead; this is done by using the galena as cathode in an electrolyte of sulphuric acid, the sulphur of the galena going off as hydrogen sulphide. (See Electrochemical Industry, September, 1902, p. 18.)

His older type of cell had two serious disadvantages: First, the operation was not continuous; second, the reduction of galena to lead was not complete. These disadvantages have now been overcome; by the use of his new cell, the process has been made continuous, while the reduction is now nearly complete (about 98 per cent). The incomplete reduction in his former apparatus was due to the use of too thick a layer of galena; by diminishing the thickness of the layer of ore, he found the reduction to become more and more complete; but for very thin layers of ore the old type of cell was not suitable. At the same time he found that a much higher current density than formerly used now becomes thoroughly feasible. He now uses a current density of 30 amperes per square foot and thinks he may go up to 60 amperes. This reduces the time required for reduction enormously (about 1½ hours now, against five days before).

His new cell is shown in the adjoining diagram. A is a wooden table on which the cell is mounted. The cell consists of an annular body B, of a trough-shaped cross-section, with inner and outer peripheral walls bb. It is composed of antimonial lead and is made a cathode by means of the connection b'b'. The anode consists of a series of segmental plates H, supported by the spider frame D, and bridging the spaces between seven of the eight arms of the spider frame D, the space between the seventh and eighth arm being left open. Current connection to the anode is made through the socket C and upright post c. Either the anode or the cathode is rotated by mechanical means, and the reduction of the galena is completed when the revolving electrode has made a complete revolution, i. e., in about 1½ hours under the present conditions.

In order to prevent the escape of gases anywhere else but through the pipe h, both of the peripheral surfaces of the ring formed by the anode segments are provided with rubber petticoats *o o*, which sweep against opposite walls of the cell B. A box which is filled with the material to be acted upon is arranged in the open space between the seventh and eighth arms of the spider frame, and is provided with a feeding slot, by which a continuous stream of material, the thickness of which can be varied, is fed to the bottom of the cell. A scraper-plate is also arranged which, as the annular anode rotates, sweeps the spongy mass out of the apparatus.

Formerly the handling and removing the electrodes had dangerous and injurious effects upon the workmen. This has now been completely overcome. (See also the notes on the present plant of the Electrolytic Lead Reduction Company at the end of this report.)

The paper was not discussed.

### Electrolysis of Sodium Hydroxide by Alternating Current.

A paper on this subject was presented by Mr. Carl Hambuechen, and in absence of the author it was read by Prof. C. F. Burgess. As is well known, the author and Prof. Burgess have developed jointly an alternating current rectifier, based on the property of the aluminium electrode, to act as an electrolytic "valve", allowing the current to pass in one direction, but not in the other direction; their rectifier consists of an aluminium and an iron electrode in fused sodium nitrate as electrolyte. In the present paper the author describes the application of this property of aluminium to the construction of a cell which acts both as a rectifier and an electrolyzing cell, for the production of metallic sodium from fused sodium hydroxide (which does not attack seriously aluminium while aluminium is actively corroded by an aqueous solution of sodium hydroxide.) The e. m. f. required for this electrolysis is 4 volts, while the aluminium retains its property to act as electrolytic valve in this electrolyte up to 40 volts. The arrangement of the apparatus is as follows:

In an aluminium vessel sodium hydroxide is fused; in it is placed an aluminium electrode and, surrounding it, an iron electrode. A perforated aluminium diaphragm is interposed between the aluminium and iron electrodes, and the aluminium electrode is insulated from the surrounding aluminium diaphragm by a porcelain sleeve at the top.

When the electrodes were connected to a source of alternating current, a current of 9 amperes, as indicated by a direct-current instrument, was passed through this cell, and after some time globules of fused sodium appeared on the surface. By operating the cell for several days, a considerable quantity of metallic sodium was collected. It was found that careful regulation of the temperature was necessary to pro-

duce a large yield, but, other than this, the cell required no attention. At the end of the run the aluminium electrode showed almost no corrosion, the only indication of it being at the top, at the point where the aluminium was in contact with the porcelain. As a result of a run to determine the amount of corrosion of the aluminium, it was found that an electrode 1.5 inches long and 0.5 inch in diameter lost about one-half gram during a run of 50 ampere-hours. The sodium, upon being liberated, rose to the surface of the liquid, and was prevented from diffusing over the other electrode by means of the aluminium diaphragm.

To determine the effectiveness of the aluminium as an electrolytic valve, current and pressure curves were obtained by means of a Blondel oscillograph. These measurements showed the existence of a small leakage current representing a loss of energy which is wasted unless its heating action is useful in maintaining the cell at the proper temperature. From the curves plotted as results of these measurements, the ampere-hour efficiency was determined to be 73 per cent. The alternating pressure wave form was peaked, while from previous measurements it is proven that a sinusoidal or flatter wave form gives a higher efficiency, so that a higher efficiency of 79 per cent can be realized under other conditions.

The aluminium diaphragm is considered as a new feature. Prof. Burgess has suggested that in its use its property to act as an electrolytic valve may be utilized; the perforations in the aluminium diaphragm may be small and at the same time allow a high current density without the current passing through the aluminium. In the aluminium diaphragm employed in the experiments, no corrosion occurred except at the surface of the electrolyte, where the diaphragm projected from the fused salt; there was a slight corrosion at this point, which could probably be accounted for by the absorption of moisture by the electrolyte when it was allowed to cool.

The author thinks that the same method of operation of an electrolytic cell might be applied for obtaining various electrolytic products other than sodium. While the current efficiency is less than if a direct current be employed, this loss may be partially balanced through avoiding the losses of a rotary converter, required if the supply mains give alternating current.

### Electrolysis of Water.

Dr. Joseph W. Richards and Mr. Walter S. Landis then presented a paper in which they give an account of their continued investigation in this field, a first paper on the same subject having been presented at the New York meeting of the society. (See Electrochemical Industry, May, 1903, p. 316.) In their former paper they showed the application of Ohm's law alone to dilute sulphuric acid for voltages up to 3.5 volts. The authors found that their former apparatus in which they used a tube 8.75 long to get a high resistance was unwieldy; they modified it, producing high resistance by the use of short capillary tubes. The cell used in their new experiments consists of two vessels containing the electrodes and connected with each other by a capillary tube, the length of which can be varied to obtain the required resistance.

The authors found that there are two very important factors to be taken into account, viz. the current used and the size of the electrodes. Probably these two factors are not entirely independent of each other, but the authors had not the means at their command to determine this relation.

The size of the current which can be used depends apparently on the amount of decomposition which can be taken care of by the dissolved gases in the solution. On account of the very small amount of diffusion which can possibly take place within the cell used, the diffusion current could be left out of consideration. The current was regulated by the resistance interposed by the cell, which could be varied to suit the electrolyte used. The size of the electrodes is also an important factor. There seems to be a certain minimum size which is necessary in order that the products of decomposition may be taken care of (recombined) as fast as they are formed.

The results of the experiments of the authors when plotted in form of curves show the curve representing the current as function of the applied volts to be a straight line, and are mainly in very good agreement with the numerical values calculated from Ohm's law on the basis of Kohlrausch's conductivities of solutions. The authors think that on account of this agreement, this method may be of use in determining specific resistances of electrolytes from which oxygen and hydrogen are evolved under ordinary conditions. It is convenient, inasmuch as it allows the employment of direct current, requires no resistance in the circuit other than that of the cell or adjustment of the same, and the required calculations are easily performed. The conditions which must be observed in using this method, are: The current must be kept within the limit of that which can be completely depolarized by the gases in solution in the electrolyte; the electrode surface must be large enough to allow this depolarization to take place simultaneously with the decomposition, and the current readings are the maximum values obtained immediately on closing the circuit, the electrodes being free from polarization before connection is made.

The smaller the electrodes which are used, the stronger is the polarization. A very interesting result obtained by the authors in their further investigation is that an evolution of gas may be obtained at a voltage between 1.15 and 1.42 at a small electrode when opposed to a large electrode, and that this is true for both oxygen and hydrogen. At the large electrode there is no gas development, but the gas which would be evolved there is taken care of by the gases dissolved in the solution; the large electrode surface means that there are enough dissolved gases in contact with it to act as depolarizer. The authors also studied the diffusion current, their results agreeing well with those of Bigelow.

In the discussion which followed, Mr. C. J. Reed, in a sarcastic mood of mind, suggested the term "undervoltage" for the fact that gas is produced with a low voltage at a small electrode when opposed to a large one. He thinks that in this case the large platinum electrode forms a compound and thus acts itself as depolarizer.

Mr. Hering asked what was the exact time when the authors took their readings, and considered this to be very important, as the values of the readings taken depend largely on the time when they are taken. Dr. R. Gahl replied to Mr. Reed that if he wants to use the term undervoltage for the phenomena in question, it would be not at all analogous to the customary term overvoltage; overvoltage means the surplus of voltage required for the development of hydrogen at a cathode of a certain material over the voltage required at platinized platinum, all other things being unchanged; thus, the overvoltage is a property of the material and platinized platinum is taken as standard, to have a convenient zero point for the scale of overvoltage.

Dr. Richards, in reply to Mr. Reed, said that he had found no chemical change of the large platinum electrode in the experiments in which it was opposed to a small one. In reply to Mr. Hering, he said that the readings were taken at 7 seconds after closing the current, because this was the time required for the needle of his instrument to come to rest. The constancy of the readings prove that they are not accidental.

## Saturday Session.

### Spark Discharges Through Water Vapor.

A paper on this subject was presented by Mr. F. Austin Lidbury. The author referred to the fact that the chemical phenomena which accompany the discharge of electricity through gases, in comparison with those connected with the passage of electricity through solutions, have received scanty attention from investigators. It is well known that many compound gases suffer decomposition to a greater or less extent

by the discharge of electricity through them, and no less well known that an actual separation of the constituent gases, bearing at least a superficial resemblance to the process of electrolysis in liquids, occurs in certain cases. In the majority of these cases the evidence of separation is purely spectroscopic. The investigation of such separations from the electrochemical standpoint has, however, been meager in extent, and practically confined to the single case of water vapor.

From experiments made by Perrot in 1861, the decomposition of compound gases appeared to be similar to the electrolysis of solutions. This view is, however, disproved by the experiments made by the author in conjunction with Mr. D. L. Chapman. In the results obtained two very peculiar phenomena were observed. First, the separated quantities of hydrogen and oxygen in a discharge tube were far greater than were simultaneously obtained from a voltameter (nickel electrodes in caustic soda solution) in the same circuit. Second, in the partial decomposition of water vapor by the electric discharge the hydrogen and oxygen liberated tended to separate and to take up different positions in the tube, the hydrogen collecting at both anode and cathode, and the oxygen in the middle of the tube.

At present there seem to be far too little data for the construction of a satisfactory theory to explain these results, but it is to be noted that Thomson has brought forward some evidence which points to the possibility that hydrogen ions may carry either a positive or negative charge. He observed that a capillary tube containing hydrogen, on the passage of the spark, gave spectra at the anode and cathode, in which the relative brightness of the lines differed. An assumption of this kind might explain the unexpected behavior of hydrogen described above. Facts, however, rather than hypotheses, are what are needed in this particular branch of electrochemistry.

### Metallic Diaphragms.

A note on this subject was presented by Dr. Eugene A. Byrnes, and in absence of the author, it was read by Mr. C. P. Townsend. In his researches on carbon cells, with fused electrolytes (Electrochemical Industry, October, 1902, p. 58) he had used a diaphragm consisting of crushed magnetite mixed with Portland cement, and enclosed between perforated iron plates. This diaphragm is suitable for use in fused sodium hydroxide.

Many other metals may be used for such a purpose, as it appears that various conducting materials become poor conductors when used in a finely powdered form; the higher the resistance, the smaller is, of course, the liability of the diaphragm to act as a bipolar electrode. These grains may be either mixed with an inert binder, like silicate of magnesium or calcium or ferrous hydrate, and molded into a self-supporting diaphragm, or they may be used without a binder and enclosed between perforated metal sheets. For cells with a horizontal cathodic surface, a floating diaphragm may be employed.

The paper was not discussed.

### Electrolytic Dissociation Theory.

The general discussion of the electrolytic dissociation theory was then opened, three papers, by Messrs. Reed, Richards and Roeber being read as part of the discussion.

### The Theoretical Properties of Ions in Solutions.

As an introduction to the general discussion, a paper on the above subject was presented by Dr. E. F. Roeber. The author referred to the method of physical analogies or mechanical models for representing or illustrating one set of facts by another familiar set of facts. This method is in extended use in all fields of physical science, and the electrolytic dissociation theory should be considered from the same point of view as a model representing the phenomena in solutions which are electrolytes, by the model of traveling ions to which certain properties are attributed in order to suit the facts; the electrolytic dissociation theory thus resolves electrolytic phenomena into a mechanics of ions.

Faraday's law states that if $n$ is the change of valency of the element reduced at the cathode or of the element oxidized at the anode (or if one uses Prof. O. T. Johnson's notation, if $n$ is the number of positive bonds lost or gained by one atom at the cathode or anode, respectively,) then the quantity of the element reduced or oxidized by the passage of $a$ amperes for $t$ seconds is $0.0000104\ at \div n$ gramatoms. If the fact of oxidation or reduction at the electrodes is represented by the model of traveling ions a charge of 96,600 positive or negative coulombs must be attributed to each positive or negative gramion. This is the only property of ions which may be derived from Faraday's law. Concerning the nature of the charge the theory is absolutely at liberty to stipulate it, in order to make the model agree with the facts. The author referred to Nernst's view of an ion being a saturated compound of an atom (or group of atoms) with one or more positive or negative electrons. Concerning the energy change from ion to atom we cannot deduce anything from Faraday's law.

To complete the model of traveling ions, it is necessary to find a method by which it is possible to determine what are the ions in a given case, and which is the speed with which each ion travels. The solution of this question was given by Hittorf by studying the concentration changes at the electrodes during electrolysis. Kohlrausch then found the law that in an infinitely dilute solution each ion has a certain characteristic mobility which is independent from the other kinds of ions present in the solution.

The electric charge and the mobility are the two properties which must be attributed to the ion to describe all phenomena in a uniformly concentrated, infinitely dilute aqueous solution. If the solution is not uniform or not of uniform concentration throughout, the fact of the osmotic pressure must be taken into account. Nernst's theory of diffusion and of concentration cells is based on the following assumptions only: That any ion travels with a speed equal to its mobility multiplied with the force acting on it, and that this force is the resultant of two kinds of forces, the electric and osmotic: the electric forces act according to the laws of electrostatics, each $n$—valent gramion being charged with 96,600 $n$ coulombs; the osmotic forces act according to the laws of osmotic pressure which are the same as those of the pressure in gases. That these are all assumptions made concerning the properties of ions, is clearly seen from the fundamental differential equations on which the theory has been based by Planck. The author remarked that from thermodynamics alone we cannot derive new properties of ions; to apply the principles of thermodynamics to dilute solutions, we make distinct assumptions concerning a dilute solution, which find their expression in the equations for energy, volume and entropy.

The model is complete for infinitely dilute solutions, and for this case it has been found to agree absolutely with the facts. All discrepancies which have been discovered between theory and facts refer to more concentrated solutions, for which Arrhenius has developed the model that only a distinct part of the dissolved molecules is ionized, and that only these ions are "active;" he attributes to these active ions the same properties as in infinitely dilute solutions, i. e., he assumes that their charge *and mobility* remain unchanged. The trouble is that the fundamental point of this model—the determination of the degree of ionization—is also its weak point, different methods giving different results for the value of the degree of ionization as has been shown especially by Kahlenberg. Nevertheless, even for more concentrated solutions Arrhenius' model represents an approximation to the truth and has proven very useful in many respects. The ions are tools for scientific progress, and a tool should not be depreciated because it is not perfect.

### General Discussion.

The general discussion was then opened by Dr. Wilder D.

Bancroft. After the electrolytic dissociation theory had carried the chemical world by storm, new researches were made along two different lines. One set of experimenters searched for further substantiation and found that the scope of the theory may be extended much more than was probable at first; they have been very successful and believe in the theory now more than ever. The other set of experimenters, notably Kahlenberg, searched for the limitations of the theory; they have also been very successful and have shown that many generalizations formerly made are not justified by the facts. The electrolytic dissociation theory is strictly correct only for infinitely dilute solutions. The trouble with the opponents of the theory is that they have been so far unable to present an exact alternative theory.

Dr. Bancroft then referred to the fact that the dissociation theory had been originally proposed, because the molecular weights in solutions were experimentally found to have abnormal values. He emphasized that the experiments really made do not justify such a sweeping statement; its correctness rests on the assumption that the heat of vaporization is the same for pure water and, for instance, for sodium chloride; but this has never been proven by experiment. A similar apparent abnormal molecular weight was found for sodium in mercury, and was later explained, but not as being due to dissociation. Dr. Barnes is making now very exact measurements in this direction, to clear up this fundamental point.

Dr. Bancroft said that while Dr. Kahlenberg thinks he can explain everything by the affinity between solvent and solution, he has not yet developed an exact theory. It is, however, quite possible that a modification of the theory will be the outcome. The theory has already undergone modifications: early supporters of the theory thought too much of the analogy between a solution and a gas and forgot that, after all, a solution is a liquid.

Mr. C. J. Reed presented a list of those points in which he believes the electrolytic dissociation theory to be a failure. He claims that electric charges are always sources of energy, energy being evolved when a discharge takes place; on the other hand, when ions change to atoms in electrolysis, they never give up energy, but always absorb energy from an outside source. He believes that here is a fundamental inconsistency in the theory. He also thinks that the theory does not account for the electrolysis of fused electrolytes; he asks why should some part of a uniform fused salt (containing nothing else) be ionized. He referred to the experiments described by him before (Electrochemical Industry, October, 1902, p. 61), in which he observed concentration changes which he believes to be in contradiction with the theory. He ridiculed the description of the theory as a model applying for infinitely dilute solutions only. Finally he referred to the numerous investigations of Kahlenberg, and especially his experiments on instantaneous chemical reactions in non-electrolytes; he believes these experiments have proven one of the foundations of the theory to be wrong.

Mr. F. A. Lidbury replied to some of the objections raised by Mr. Reed. Kahlenberg's experiments on instantaneous chemical reactions in non-electrolytes do not contradict any fundamental part of the dissociation theory; they only prove that while the facts appear to show an intimate relation between chemical action and ionization in aqueous solutions, it was wrong to generalize this and apply it to other solutions for which no proof had been given. Concerning fused electrolytes he sees no reason why they should not be ionized just as well as pure water is ionized.

Dr. W. Lash Miller gave a brief account of difficulties which he has encountered in a recent investigation. To determine the nature of the ions in a certain case he used Ostwald's dilution law and tried then to calculate the transport numbers, but they did not agree with the facts; he does not know yet how to explain the discrepancy.

Prof. Henry S. Carhart said that Prof. Bancroft's statement of the present situation had been very fair. He considers the electrolytic dissociation theory as a very useful working hypothesis which has led to the detection of a large number of new facts. On the other hand there are very serious objections and quantitatively there are many discrepancies. He does not like the name electrolytic dissociation, because the ions are assumed to exist as ions before any electrolysis takes place. He thinks further investigations will lead to the evolution of a modified or new theory.

### The Thermochemistry of the Dissociation Theory.

A theoretical paper on this subject was presented by Dr. Joseph W. Richards as a contribution towards the discussion. He discussed the subjects of the ionization heat, heat of formation and heat of neutralization, as seen from the standpoint of the theory and from the standpoint of thermochemistry or chemical energetics. His principal thesis was that thermochemistry has established the law of the additive nature of the heat of formation of salts, reckoned to dilute solutions; that this points to each element possessing a thermochemical constant, which is the amount of heat energy which it gives off in the act of going into combination, independent of what other element it combines with, and that the element, when in the state of combination is of lower intrinsic energy than when free, by this thermochemical constant.

The rule of the heat of formation of salts being the sum of the thermochemical constants of their constituents applies approximately only to solid salts, but with almost complete accuracy to salts dissolved in dilute solutions. Therefore, the salts in dilute solutions are the most perfect types of complete "combination" which we possess. Thence results the conclusion that whatever electrolytic dissociation or ionization may be, it is most certainly *not* a resolution of the compound into its constituents or a decomposition of the compound; on the contrary, it is probably a process which brings the constituents into their most perfect state of "combination."

A similar conclusion is reached by regarding the heat of solution of salts. The solid salt is formed from its elements with a large development of heat; but dissolving it in water in excess leads to but a small development of heat, or sometimes a small absorption. Thence it results, that in the dilute solution the compound must be very much nearer in its molecular condition to the solid, undissociated salt, than to the free elements from which it is composed. Therefore, the ionized molecule (whatever that condition may be) is a condition of the *compound*, and not a condition of its constituents. The completely ionized or electrolytically dissociated salt is as much the *salt* or compound as before ionization; sodium chloride in dilute solution is still sodium chloride, as truly as in any other condition. The mere act of solution, with its accompanying ionization, is no destruction of the compound *per se*, because the energy of decomposition has not been absorbed in the act of solution. Therefore, the dissolved salt is still the compound.

A similar conclusion is reached by regarding the heat of dilution of solutions. In concentrated solutions, a salt may be ionized only a few per cent, as indicated by the usual tests. By diluting sufficiently it becomes completely ionized. But heat is usually evolved in dilution, in small amount; sometimes a little is absorbed. This heat of dilution is, however, but a very small proportion of the energy of formation of the compound; therefore, the electrolytic dissociation or ionization of the molecule, whatever it may be, is not a decomposition or destruction of the compound. The constituents of the salt are as much in the combined condition, and constitute as really a compound, in the ionized as in the un-ionized condition.

The *heat of ionization*, if there is really such a quantity, can only mean the energy absorbed in converting a dissolved molecule into dissolved ions. This quantity cannot be the heat of solution of the solid salt, because that necessarily includes the latent heat of fusion of the solid material passing into the

liquid condition, if not possibly also its latent heat of vaporization, since the salt in dilute solution exerts osmotic pressure quite analogous to a gaseous pressure. Neither is it certain that it can be derived with certainty from the heat of dilution, because there is, in many solutions, definite physical and thermal evidence of the formation of definite hydrates in solution, and their subsequent destruction or modification on dilution. Therefore the heat of ionization must not be confounded with the heat of dilution, although, if it is a real value, it is algebraically included within the dilution heat.

The author protested vigorously against Ostwald's use of the term *heat of ionization* as the heat evolved in the passage of free elements into the state of ions in dilute solution, or, rather, into constituents of ionized molecules. This change is really, from the author's point of view, the passage of the elements from the free into the perfectly combined condition, and therefore these *heats of ionization* (Ostwald's), are nothing but the thermochemical constants of the elements, evolved *when going into* combination. Such a use of the term *"heat of ionization"* is unfortunate and very misleading. As used by Ostwald, it is identical with the heat of formation measured thermochemically, and, therefore, an entirely different quantity from that required to ionize a dissolved molecule into ions. Even Ostwald himself would admit that since the sum of the "ionization heats" of two elements equals the heat of formation of their compound, the elements in the state of ions must be perfectly combined, as the chemical compound. This misleading, if not sophistical, use of this term would tend to the following erroneous conclusions on the part of students of electrochemistry: "Ionization heat" is equal to formation heat, therefore, ionization or electrolytic dissociation is really a decomposition of the compound into its constituents. The fallacy of such reasoning is evident when we consider the double meaning which Ostwald attaches to *"ionization heat."*

An interesting application of the principles so far explained was then made, by a consideration of the "heat of neutralization." In dilute hydrochloric acid we have H and Cl in the combined state, each having contributed its thermochemical constant towards the heat of formation of the HCl. Similarly, dilute NaOH contains Na and OH, both in the combined condition. After neutralization, only Na and Cl remain in dilute solution, the H and OH have become liquid water. But since the H and the OH were both in the combined state before neutralization, and also after, the heat of neutralization cannot be the thermochemical heat of combination of H and OH. We cannot write the equation (H, OH) = 13,700 calories as a thermochemical equation; and the oft-repeated statements that the neutralization constant is simply the heat of union of H with OH to form $H_2O$, as a chemical act of combination, are entirely wrong.

What, then, is the source of the neutralization heat? The author's view is that it can only be physical: that since the H and OH, occurring as HCl and NaOH before neutralization, exerted in that condition osmotic pressure analogous to gas pressure, they may be considered as having changed merely from combined H and OH in the gaseous condition into combined H and OH in the liquid state, a change entirely analogous to condensation of vapor to liquid water. Calculating the energy required to convert liquid water into gaseous molecules exerting a pressure (osmotic) of 6.1 atmospheres, and adding to this the work which would be evolved in the halving of the osmotic pressure of the NaCl molecules (after neutralization the Na and Cl are in double the volume that they were before), the physical change calculates up to 13,430 calories, which accounts almost exactly for the neutralization constant, and appears to conform the views of the author respecting the *identity* of the *"ionized"* condition with the thermochemical *combined* condition of the elements.

The author concluded that on this account the "ionized state" should be considered to be rather a state of combination than of dissociation.

### Berthelot's Law Relative to the Electromotive Forces of Cells Based on the Reciprocal Action of Saline Solutions and Soluble Electrolytes.

A paper on this subject by Mr. C. J. Reed was another contribution to the discussion. He referred to a law recently announced by Berthelot, as follows: "When a base acts upon an acid, the e. m. f. developed is the sum of the e. m. fs. developed by the reaction of the corresponding salt separately upon the acid and upon the base. The reacting solutions are supposed to be dilute, in equivalent proportions, and to give rise to no separation of gaseous or insoluble products, and to undergo no progressive change in their internal constitution other than neutralization."

Mr. Reed discussed in detail the experimental proofs advanced by Berthelot, and showed that they are absolutely unsuitable to prove this law. He then claimed that there is no experimental evidence anywhere on record that there exists really an e. m. f. at the junction of two electrolytes. All measurements are made with the use of electrodes, and the e. m. f. at the junction of electrode and electrolyte cannot be eliminated from the total e. m. f. measured. He considers the cells used by Berthelot as concentration cells.

Dr. W. S. Weedon, referring to Dr. Richards' paper, said that the state of combination of a dissolved salt must be different from the ordinary state of combination; ionization may not mean complete separation, but the ions must be independent of each other to some extent. Mr. Alfred H. Cowles said, concerning the energy relation, that it is necessary to consider the energy of the total system—solvent and solute—as a unit.

Dr. H. M. Goodwin spoke of the various fields in which the electrolytic dissociation theory has proven to be useful, and referred to the colors of solutions as explained by the theory. He then said that when investigations go along, one must expect that things come up which don't agree with the theory; this is the way in which a theory is evolved and improved. Concerning Dr. Richards' calculation of the neutralization heat, he thinks it is simpler to assume according to the dissociation theory that the neutralization of an acid by a base corresponds to the combination of the hydrogen ions of the acid with the hydroxyl ions of the base, forming water. Dr. Richards replied that the advantage of his theory is that it enables him to calculate the neutralization heat.

In the following we give an alphabetical list of all members and guests who registered at the meeting.

Charles E. Acker, Niagara Falls; Robert H. Aiken, Winthrop Harbor, Ill.; Edward L. Anderson, Mrs. E. L. Anderson, St. Louis, Mo.; I. A. Andrew, Orange, Conn.; Harry E. Baer, Mrs. M. L. Baker, New York; Wilder D. Bancroft, Mrs. Bancroft, Ithaca, N. Y.; Charles W. Barnaby, New York; I. Baum, Ithaca, N. Y.; Frederick M. Becket, P. McN. Bennie, S. D. Benoliel, Niagara Falls; Miss M. Bent, New York; Henry S. Blackmore, Mount Vernon, N. Y.; George Fred. Brindley, Niagara Falls; William Hand Browne, Jr., New York; C. F. Burgess, Madison, Wis.; R. E. Burkett, Brooklyn, N. Y.; Roy Call, Niagara Falls; Henry S. Carhart, Ann Arbor, Mich.; Charles A. Catlin, Providence, R. I.; Miss Grace Adele Clark, Brooklyn, N. Y.; George B. Cock, Philadelphia; Charles Welles Coit, Niagara Falls; E. A. Colby, Newark, N. J.; C. L. Collins, 2d, Miss Collins, Niagara Falls; Alfred H. Cowles, Cleveland, O.; C. E. Cox, Niagara Falls; L. Douglas Crane, New York; J. S. Crider, Cleveland, O.; J. L. Danziger, New York; H. T. Darlington, Philadelphia; William Dreyfus, New York; Wilber S. Earl, Henry S. Ely, Niagara Falls; C. A. Ernst, Schnectady, N. Y.; Miss Fenner, Providence, R. I.; Francis A. J. Fitzgerald, R. E. Fowler, S. P. Franchot, Niagara Falls; Rudolf Gahl, Mrs. Gahl, Philadelphia; D. E. Goldsborough, Lafayette, Ind.; H. M. Goodwin, Boston; A. Monro Grier, Charles M. Hall, S. F. Hall, Niagara Falls; Louis P. Hamilton, Dunbar, Pa.; George R. Harlow, Pittsburg; William D. Harris, Philadelphia; M. Hartwig, Buffalo; F. W. Haskell, Niagara Falls; Charles Haslwanter, Brooklyn, N. Y.; Carl Hering, Philadelphia; F. W. Higgins, Niagara Falls; B. H. Hite, Morgantown, W. Va.; Norman Holland, W. S. Horry, Niagara Falls; George M. Howard, Philadelphia; H. A. Irvine, Niagara Falls; Otis C. Johnson, Ann Arbor, Mich.; Woolsey McA. Johnson, Iola, Kan.; W. A. Johnston, Princes Bay, N. Y.; Miss M. S. Kennedy, Morristown, N. J.; A. E. Kennelly, Cambridge, Mass.; A. A. Knudson, New York; Mrs. A. A. Knudson, Brooklyn, N. Y.; R. N. Kofoid, Joseph Kuhn, Niagara Falls, Miss C. A. Lee, Rochester, N. Y.; Miss M. L. Lee, Weedsport, N. Y.; E. B. LeMare, Manchester, Eng.;

J. Austin Lidbury, Niagara Falls; James Locke, Boston, Mass.; Henry M. Loomis, D. R. Lovejoy, George F. Lull, Mrs. G. F. Lull, Niagara Falls; J. MacMahon, La Salle, N. Y.; Cloyd Marshall, St. Louis, Mo.; John A. Mathews, Syracuse, N. Y.; H. T. Matthew, New York; Max Mauran, Niagara Falls; W. Lash Miller, Toronto; I. J. Moltkehausen, Perth Amboy, N. J.; C. H. Moritz, Niagara Falls; Henry G. Morris, Philadelphia; William L. Nadolsky, New York; Henry W. Newton, Buffalo; R. I. Nunn, Savannah, Ga.; Ross Phillips, Charles Pretzfeld, W. B. Rankine, G. R. Raynor, Niagara Falls; C. J. Reed, Philadelphia; Joseph W. Richards, Bethlehem, Pa.; I. C. Roberts, Niagara Falls; E. F. Roeber, New York; Ashmead G. Rodgers, Niagara Falls; Marcus Ruthenburg, Michael Sack, Lockport, N. Y.; P. G. Salom, Philadelphia; L. E. Saunders, F. E. Schmitt, Niagara Falls; George P. Scholl, Philadelphia; Charles T. Scott, Pittsburg, Pa.; Edmund S. Smith, E. C. Sprague, Niagara Falls; T. E. Steere, Niagara Falls; H. H. Stock, E. M., Scranton, Pa.; S. W. Stratton, Washington, D. C.; Maurice deKay Thompson, Jr., Boston; Elihu Thompson, Swampscott, Mass.; Clinton P. Townsend, Washington, D. C.; R. A. Trasch, New York; A. Van Winkle, Newark, N. J.; Chas. F. Vaughn, Niagara Falls; Miss Vaughn, Providence, R. I.; Alois von Isakovics, New York; W. H. Walker, Boston, Mass.; A. Sydney Warren, Buffalo, N. Y.; Wm. S. Weedon, Mrs. Wm. S. Weedon, Schenectady, N. Y.; Sam'l Weil, R. H. White, Niagara Falls; E. H. Whitlock, Cleveland, O.; Henry Wigglesworth, New York City; McKenzie Williams, Toronto; J. M. Wills, Akron, O.; J. Rattray Wilson, R. A. Witherspoon, Niagara Falls; H. H. Withey, St. Louis, Mo.; Ira H. Woolson, New York; A. J. Wurts, Pittsburg, Pa.

### Visits to Plants.

Visits of plants were made on Thursday, Friday and Saturday afternoon. The following companies had extended invitations to the society as a whole: The power plant companies, the Niagara Research Laboratories, and the National Battery

ELECTROLYTIC LABORATORY, NIAGARA RESEARCH LABORATORIES.

Co. in Buffalo. Groups of individual members visited various other plants, among them the works of the Acker Process Co. and the Electric Lead Reduction Co., and Mr. Ruthenburg's experimental furnace plant in Lockport, N. Y. Electrochemical Industry has already published detailed descriptions of the power houses (1902, September, p. 12), of the Acker plant (1902, October, p. 541), and of the accumulator type made by the National Battery Co. (1902, December, p. 148). In the following we give brief sketches of the other plants visited. At the plant of the National Battery Co., in Buffalo, Mr. Elmer A. Sperry conducted the visitors through the works; the company had provided refreshments.

### Niagara Research Laboratories.

The Niagara Research Laboratories represent a new departure in the development of electrochemistry in the United States. The company was founded "to maintain a research laboratory for scientific investigations; do analytical and experimental work for the general public; act as consulting engineers in perfecting or improving existing processes; rent space and power for chemical and electrochemical investigations; to manufacture and sell chemicals and allied products." The officers of the company are Messrs. E. B. Stevens, William B. Rankine, Elmer J. Starr and Fred. M. Becket. The engineering staff consists of Messrs. Fred. M. Becket, R. A. Witherspoon and L. E. Saunders.

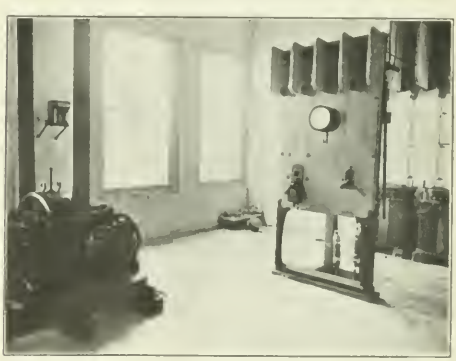
The three-story building of the Niagara Research Laboratories is in the immediate neighborhood of the works of the Electric Lead Reduction Co. The second floor contains the general offices, the library, the electrolytic laboratory, and the analytical laboratory. In order to permit of high temperature electrolytic work, a separately excited 16-kw. generator has

ANALYTICAL LABORATORY, NIAGARA RESEARCH LABORATORIES.

been installed (in the basement), which gives 1000 amperes at 16 volts, or 2000 amperes at 8 volts, thus affording sufficient energy for the development of commercial units. As this generator is supplemented by a storage battery outfit and by rheostats for regulation, electrolytic work of any description may be undertaken.

The adjoining illustration of the electrolytic laboratory (Fig. 1) shows the table for electrolytic experiments in the back. The surface of the table contains nothing but the binding posts for making the connections, the measuring instruments and the apparatus in which the experiments are made. The switches and regulating rheostats are placed on a shelf underneath, which also holds a number of storage cells to be used when electrolytic work is to be carried on over night.

Fig. 2 shows the room for analytical and general chemical work. It is equipped in a modern way for the analysis of such organic and inorganic compounds as may be met with in commercial work, and with facilities for general chemical research. Among the various apparatus which it contains we noticed a Seward apparatus for determining carbon in ferrochrome, etc., (Electrochemical Industry, 1903, June, p. 366), and a very convenient electric drying oven, the heating and the regulation



CONVERTER PLANT AND SWITCHBOARD, NIAGARA RESEARCH LABORATORIES.

of the temperature being accomplished by a set of incandescent lamps. A larger drying oven of the same type will be shortly installed. A small adjoining room contains the analytical balances.

The surface plates of all tables in these rooms are of slate.

with longitudinal grooves. They are of historical interest, having formerly been used in the electrolytic cells of the Castner Electrolytic Alkali Co. (which now use concrete tanks); for the present use, the slate plates appear to be ideal.

The ground floor contains converter and transformer plant, the machine shop, the grinding room, and the electric furnace laboratory. Fig. 3 shows the room containing the converter plant. The 16-kw. separately excited direct-current generator which, as mentioned before, gives 1000 amperes at 16 volts, or 2000 amperes at 8 volts, is an Eddy double commutator machine, while all other machines are made by the Westinghouse Co. It is driven by an induction motor, fed with alternating current from the supply mains. The same room contains the controlling board for a 500-hp. transformer, erected in the next room, which changes the alternating current voltage from 2200 to 110 or 55 volts for electric furnace work. A water resistance is installed for regulating the voltage; it is able to carry 8000 amperes, and to consume 50 volts. There is also a smaller transformer of 175 kw.

Fig. 4 shows part of the furnace room. On the left side there is a larger furnace. For furnace lining brown coke and tar is used. At the right hand a smaller furnace is seen; a number of similar ones are to be erected next to it, and all these furnaces are to be arranged in a circle. As seen in the illustration, there is provided a crane with a hanging electrode;

ELECTRIC FURNACE ROOM, NIAGARA RESEARCH LABORATORIES.

by swinging around, this electrode may then be used for any furnace in the circle.

With the view of facilitating the ready setting up of experiments, the machine shop on the ground floor has been equipped with a 21-inch drill press, power forge, a complete set of bench tools, etc. The grinding room contains machinery for the crushing and pulverization of ores, having a capacity of about two tons of rock per day.

Although the entire equipment of the laboratories is at the disposal of experimenters, there have been set aside limited spaces which can be completely isolated, and in which work of a patentable nature may be carried on with the utmost secrecy. Alternating and direct current, gas and water may be had in these rooms, and, if desired, a belted connection with the main line shaft.

### Electric Lead Reduction Works.

The visit to this plant reminded us of the untimely death of the chemist of the company, Mr. Alfred J. Weightman, who extended many courtesies to the visitors of the plant a year ago, and who at that time presented to the society an interesting paper on the theoretical questions of the Salom process. An illustrated description of the former installation of this plant was published on page 18 of our September number, 1902; but since that time the general appearance of the electrolysis room has greatly changed. The rows of stacks, each of 11 pans, one placed above the other, have disappeared, since the new form of cell, described above in the abstract of Mr. Salom's paper, has been installed.

There is at present one row of 17 cells in the middle of the room. Each cell looks somewhat like a wheel in a horizontal position. In the present arrangement the cathode which forms the bottom of the cell is rotated, completing one revolution in 1½ hours, which is also the time in which the reduction of galena to lead is completed. The size of the different anode compartments at the top of the cell varies from one compartment to the next in order to diminish automatically the current density, when the reduction becomes more and more complete. The present arrangement has evidently reduced the cost of labor to a large extent. Even under the present conditions in which the feeding of ore to the cathode surface and the scraping off of the reduced spongy lead is done by hand, it is estimated by Messrs. Morris and Salom that three men would be sufficient to do the whole work if the plant were fully equipped.

Some experiments have been made to convert the hydrogen sulphide into sulphuric acid, but the gases are at present mostly wasted. The original intention to utilize the gases which are evolved in gas engines for driving the electric generators has not yet been carried out. It will be remembered that this is theoretically very promising, because the energy of the burning gases is greater than the energy required in the electrolytic process. (J. W. Richards, Transactions American Electrochemical Society, vol. I., p. 931.)

### The Plant of the Cowles Co. and the Ruthenburg Iron Furnace.

The experimental iron furnace of Mr. Marcus Ruthenburg is installed in one room of the works of the Cowles Co. at Lockport, N. Y. These works, in a pretty location in a valley between wooded hills, contain much of historical interest. The two Brush machines were considered, at the time of their installation (1886), to be the most powerful generators of the world. The principal output of the Cowles works is at present silicon-copper, used for copper castings. Cuprous oxide dissolves in fused copper, and this is the reason why the making of good uniform copper castings involves great difficulties. These are overcome by adding a small amount of silicon-copper; the silicon combines with the oxygen of the cuprous oxide to form silica. Silicon-copper is used at present to a large extent for this purpose. The original charge is melted in a Cowles furnace of the well-known type with two sliding carbon rods as electrodes. The product of the electric furnace is analysed and then remelted to bring it up to the standard composition.

The Ruthenburg iron process and furnace have already been described repeatedly in Electrochemical Industry (November, 1902, p. 84, and February, 1903, p. 202). The two illustrations given in the above abstract of Mr. Ruthenburg's paper are made from photographs of his furnace in Lockport. They show the horizontal horseshoe magnet, the poles of which are within the slowly revolving rolls. In the small space between these rolls the crushed ore forms a magnetic bridge, and is melted and agglomerated; it then becomes unmagnetic and drops into the soaking pit. The greatest part of Mr. Ruthenburg's recent work has been confined to the study of the best method of producing the reduction in the soaking pit. This occurs by passing hot hydrocarbon gases upwards through the soaking pit (which is about five feet high). The reduced iron is then ready for making steel in a Siemens furnace.

## THE PRECIPITATION OF GOLD FROM CYANIDE SOLUTIONS.*

By W. A. Caldecott and E. H. Johnson.

The precipitation of gold from cyanide solutions is a matter which has often been discussed, and a considerable

* A paper presented to the Chemical, Metallurgical and Mining Society of South Africa.

literature already exists upon the subject. At the same time, in spite of its primary importance, in that, after the preliminary operation of dissolving, it is precipitation which concentrates the gold from auriferous material in a solid form, many of the reactions involved are still doubtful. Besides the complexity of the subject, this is no doubt due to the fact that the majority of those engaged in the actual conduct of gold precipitation have their energy fully occupied in the actual running of the plant, and that there is little time available for pure research and extensive investigation, from which an immediate and definite profit cannot be guaranteed. It hence follows that any attempt to explain the reactions which occur must be based on the observation by various workers of various isolated facts. The reactions intermediate between observed phenomena can at present only be explained by that hypothetical reasoning which seems most probable until more is actually known. Though not absolute, such tentative conclusions may be of use, as shown, for instance, in the parallel case of the practical recognition of the validity of Elsner's equation, indicating the utility of oxygen in the dissolving of gold, long before it was proved to be quantitatively correct by Maclaurin.

One view of gold precipitation based on the ionic theory has been dealt with by Prof. von Oettingen, and by Prof. Christy; but, although this view, when fully worked out, may prove the more correct, at present its comparative novelty and the complexity of the reactions of double metallic salts, such as potassium aurocyanide, may render the elaboration of an older and simpler hypothesis of more use to some of us, as a working tool for the time being. This latter view to which we refer is based on the hypothesis that the precipitation of metallic gold from solution may be conveniently and comprehensively regarded as due in practice to the reducing action of nascent hydrogen, which replaces the gold in solution. We are encouraged to consider an explanation of gold precipitation other than the ionic, by the opinion expressed by Bertram Blount, that "the practician * * * can grapple successfully with any problem * * *, irrespective of the precise explanation which may be at the moment most agreeable with the teachings of the ionic hypothesis."

In 1892, B. C. Molloy patented a precipitating agent for gold from cyanide solutions in the shape of an amalgam containing an alkaline metal, which he stated to yield nascent hydrogen when in contact with the solution. Louis Janin, Jr., states in an article on the cyanide process, published in Vol. 1 of the *Mineral Industry* (1903), that "hydrogen is always evolved when the gold is precipitated" in the zinc boxes, and W. R. Feldtmann in his pamphlet (1894) on the cyanide process on the Whitwatersrand surmises that "the accelerating influence on precipitation of excess of potassic cyanide is probably due to generation of nascent hydrogen." But earlier than all these references was the recognition by the first workers on the cyanide process of the fact that effective precipitation was always associated with a "good action," or vigorous evolution of hydrogen bubbles in the zinc boxes.

One of the main features in the precipitation of gold from cyanide solutions is that it exists therein in the form of potassium aurocyanide ($KAuCy_2$). In this state the gold does not form the basic portion of the compound, as it usually does with metals in combination, but is part of the solid radicle $AuCy_2$, which is combined with the potassium as a salt of the hypothetical aurocyanhydric acid ($HAuCy_2$). This compound is similar to cuprosocyanhydric acid ($H_2Cu_2Cy_4$), and is stated to have been prepared in solution in 1878 by C. G. Lindboom (*La Société Chimique*, Tome 29, No. 9.) by addition of sulphuric acid to barium aurocyanide ($BaAu_2Cy_4$). The solid radicle, $AuCy_2$, is exceedingly stable or difficult to entirely decompose, and its tendency to form comparatively soluble compounds renders it difficult of precipitation. The gold may, however, be replaced by H and caused to assume the solid form, or the potassium may be replaced by some other metal such as silver or copper (cuprosum), in which case the gold comes down as an insoluble double metallic cyanide. This latter reaction is, of course, only possible in the absence of free potassium cyanide, in which all cyanides are soluble. In consequence, though equally perfect results can be obtained either way, the former is, so far, the only method for gold precipitation on a large scale, and the latter, involving the destruction of free cyanide, is at present usually confined in practice to one stage in the "precipitation method" of assaying cyanide solutions.

One grain of gold per ton of solution is equivalent to one part by weight in fourteen millions; any method of precipitation which leaves in solution more than one part of gold in ten millions of solutions, cannot, from a working standpoint, be considered first-class; with 2 dwt. solution this would be about equivalent to 97 per cent efficiency.

The precipitation of gold in cyanide solutions is essentially in practice a process of reduction, just as its solution is conversely a process of oxidation. This is obvious if we compare the equations representing in the simplest form the two reactions:

(a) Solution of gold:

$$4KCy + Au_2 + O + H_2O = 2KAuCy_2 + 2KOH.$$

(b) Precipitation of gold:

$$2KAuCy_2 + 2H + 2KOH = Au_2 + 4KCy + 2OH_2$$

The nascent hydrogen indicated in the latter equation is one of the most powerful reducing agents known at ordinary temperatures. It is readily evolved in cyanide solutions, as, for instance, by zinc shavings (MacArthur-Forrest process), zinc dust, sodium amalgam (Molloy's and Zerener's processes), aluminium-mercury couple (Moldenhauer's process), and various zinc couples (such as zinc-lead, zinc-mercury, zinc-copper, zinc-iron, etc.)

The explanation of electrolytic precipitation of gold from the ionic standpoint may be expressed in the following extract from Macmillan's *Electro-Metallurgy* (1899): "It may be shown that the gold travels with the ion which migrates from cathode to anode, and only the potassium migrates from anode to cathode, yet the gold is deposited only to the cathode. This is due to chemical reaction. The ions of such a cyanide ($KAuCy_2$) are apparently K and $AuCy_2$, the K-ion giving up its charge at the cathode, but immediately attacking the solution in contact with it and depositing, not hydrogen, but gold from the liquid around, because potassium can break up the complex aurocyanide of potassium that is present

$$KAuCy_2 + K + H_2O = 2KCy + Au + H_2O.$$

Thus gold is deposited at the cathode, not because ions of free gold exist in the liquid, but because potassium is deposited and changes place with the gold in the complex substance $KAuCy_2$ in contact with the cathode. At the same time, gold does not form at the anode, because the ion $AuCy_2$ cannot exist alone in the liquid, but breaks up into cyanogen, Cy, and gold cyanide $AuCy$, which redissolves in the free potassium cyanide in the solution, reforming potassium aurocyanide. The free cyanogen is then able with its negative charge to allow of the passage of another atom of gold to withdraw its positive charge from the anode, and to pass into the ionic condition."

Viewing the equation quoted above from the ordinary chemical standpoint, and assuming the reaction it indicates in this sense as occurring, an intermediate stage may be inserted thus:

$$KAuCy_2 + K + HO = KAuCy_2 + H + KOH$$
$$KAuCy_2 + H + KOH = 2KCy + Au + H_2O$$

In other words, the intermediate stage corresponds to the equation (b) previously given as indicating the precipitating of gold by nascent hydrogen. On this hypothesis it appears that the nascent hydrogen produced by electrolysis of the water may also serve to precipitate the gold. In the case of ordinary zinc (really an alloy of zinc with negative elements

such as lead, iron, carbon, etc.) and of zinc couples, water is also decomposed with evolution of nascent hydrogen and deposition of the gold on the less positive element, and with liberation of oxygen at the zinc. This primary reaction, if viewed from a thermal standpoint, thus:

$$Zn + OH_2 = ZnO + 2H.$$
$$69.0 = 86.4 \qquad -17.4$$

calories indicates a strongly exothermic reaction, or in other words, the hydrogen is liberated owing to the superior affinity zinc has for the oxygen of water; the free potassium cyanide serves to assist the reaction by continually dissolving away the coating of zinc hydrate formed and presenting clean metallic surfaces in contact with the solution.

The same reasoning applies with an amalgam containing an alkaline or alkaline earth metal, or with a magnesium or aluminium couple, or with any metal or metallic couple of which the more electropositive element possesses a stronger affinity for the oxygen in water than does the hydrogen combined with it. The function of the less positive metal in the couple appears to be that of affording a locus, in the shape of innumerable points or roughnesses, for the liberation of hydrogen away from the oxygen simultaneously liberated, at the more positive metal. By this separation the reducing action of the hydrogen, possibly in some cases occluded in the less positive metal, is not interfered with. Mr. MacArthur informed one of the writers that the precipitating efficiency of chemically pure zinc is almost nil. In a suggestive paper read by Mr. Ehrmann before the Chemical, Metallurgical and Mining Society of South Africa in April, 1897, he quotes some very interesting experimental results with zinc and the zinc-copper couple to show that the precipitating efficiency increases with the volume of hydrogen liberated from the solution in the respective instances.

Even if the view expressed in most text books of precipitation being caused by the dissolving of the zinc to directly replace gold in solution be taken it amounts to much the same thing, except that the nascent hydrogen is set free from the water by the potassium liberated by the solution of the zinc instead of by direct decomposition of the water, thus:

$$Zn + 4KCy + 2H_2O = K_2ZnCy_4 + 2KOH + 2H$$
$$2KAuCy_2 + 2KOH + 2H = Au_2 + 4KCy + 2H_2O.$$

or, eliminating similar compounds on both sides, we obtain the equation usually given:

$$Zn + 2KAuCy_2 = K_2ZnCy_4 + Au_2.$$

In all methods of precipitation the liberation of oxygen is a source of trouble; in electrolytic precipitation the anodes constantly waste away, mainly for the same reason as zinc in the MacArthur-Forrest process, and the discovery of a practicable permanent anode is still a subject for research. Besides the waste of material the formation of the oxidation products in the extractor box interfere with efficient working. In case of zinc, as it wastes away, the oxide formed reacts further with the solution yielding various products.

In the Siemens & Halske and electrolytic processes generally the energy required for the precipitation of the gold is originally derived from the burning (or oxidizing) of coal in the boiler-room, whereas in the case of ordinary zinc or zinc couples it is derived from the oxidation (or burning) of zinc in the solution. Hence, in the former case the efficiency of precipitation is not directly dependent upon the strength of the solution, but upon the electric energy applied, whereas in the latter it depends upon the rate of oxidation of the zinc, which increases with the strength of the solution and its cleansing effect already referred to. This cleansing effect may be compared with the dissolving of zinc in sulphuric acid. Speaking of the action of water on zinc, Macmillan says (*Electro-Metallurgy*, p. 349): "The action must stop almost at once, because solid, undissolved and insoluble zinc hydroxide $Zn(OH)_2$ would be formed on the surface of the zinc, and so gradually prevent further contact between the water and the zinc. But when an acid, sulphuric acid, for example, is substituted for water, the action is different, for zinc sulphate ($ZnSO_4$) is soluble in water."

When comparatively strong cyanide solutions (say 0.07 per cent and upwards) are used, the products of oxidation of the zinc dissolve as they are produced, and the efficiency does not decrease. With weak solutions (say 0.01 per cent to 0.03 per cent), however, they do not wholly dissolve, but accumulate in the extractor boxes as a coating on the zinc, thus gradually impairing its efficiency by keeping it from actual contact with the solution until it practically ceases to act. Deposits of finely divided matter from unfiltered turbid solutions act in the same way. The silica found in the zinc boxes is probably mainly due to mechanical causes, such as dust and slight defects in filtering, but may also be partially derived from the charge owing to the slight solubility of silica and silicates in the alkaline solution. Sulphate of lime, produced when treating acid tailings or slimes which require much lime, is also liable to crystallize out from the cyanide solution which is saturated with it upon the precipitating agent.

The deleterious effect of calcium sulphate in solution upon electrolytic precipitation, owing to its small conductivity, has been investigated by Mr. A. F. Crosse. Among other coatings zinc sulphide can usually be detected, and its formation is apparently due to alkaline sulpho-cyanides in the solution, which serve as a carrier of sulphur from the ore or the commercial cyanide used to the boxes. The reactions seem analagous to those of gold, being probably due to oxidation first and then reduction, as shown in the following typical equations:

(a) $FeS + 6KCy = K_2S + K_4FeCy_6$
$K_2S + KCy + O + H_2O = KSCy + 2KOH.$

(b) $KSCy + Zn(OH)_2 + 2H = ZnS + KCy + 2H_2O.$

It seems possible that selenium acts similarly to sulphur, as at the Redjang Lebong Mine in Sumatra the zinc gold slimes as cleaned up from the boxes were found to contain up to 3.4 per cent selenium (Proc. I. M. M. 23d April, 1903). The presence of common salt and ammonium salts in solution appears to assist precipitation, owing to their slight solvent effect on the zinc hydrate formed. Caustic alkalies should presumably act in this way also, but in practice they seem to have the opposite effect, and to induce the formation of zinc hydrate to a still greater extent than the alkaline zincate formed serves to remove it. The presence of alkaline carbonate in commercial cyanide serves when lime is used to form caustic alkali in the solution thus:

$$Na_2CO_3 + Ca(OH)_2 = CaCO_3 + 2NaOH.$$

Mechanical removal of the zinc coatings is effected to some extent by the ordinary practice of washing, and the use of a dilute acid solution for this purpose has also been suggested. A most efficient aid to zinc precipitation would be the discovery of some innocuous solvent for zinc hydrate compatible with cyanide.

Increase of temperature, as shown by Mr. Ehrmann, accelerates precipitation from its natural tendency to promote chemical reactions, with of course increased zinc consumption. In the absence of free alkalies and presence of the hydrocyanic acid, there does not seem much tendency to form zinc hydrate, thus:

$$Zn + 2HCy + 2KCy = K_2ZnCy_4 + 2H.$$

Apart from undissolved zinc hydrate, the general interaction of zinc, potassium cyanide, and caustic alkali may be expressed as follows:

$$Zn_2 + 4\,K\,Cy + 2\,(x-1)\,K\,O\,H$$
$$= 4\,H + K_{2x}\,ZnO_{x+1} + K_2\,Zn\,Cy_4 + (x-3)\,H_2\,O$$

x is a variable quantity, increasing with the dilution of the solution in alkali, and always much greater than indicated in the ordinary formula for potassium zincate, namely $K_2ZnO_2$. The relative amount of zinc as double cyanide and zincate respectively, in the solution leaving the boxes is possibly in proportion to the respective amounts of free potassium cyanide

and caustic alkali in solution. Hence, on adding additional alkali a certain amount of zinc is transferred from the cyanide combination to the state of zincate and the percentage of free cyanide in solution consequently increased.

It might be expected, from the formation of nascent hydrogen in the boxes, that all dissolved oxygen in the solution leaving them would be removed, and Mr. A. F. Crosse's analyses show this to be the case.

The great barrier to continuously effective precipitation is lack of contact between the precipitating surface and the solution, and owing to the readiness with which this surface becomes coated in various ways, as shown, it is necessary to employ enormous areas to ensure good results. A pound of ordinary zinc shavings exposes about forty square feet of surface, and hence every ton of shavings in the boxes is equivalent to nearly two acres. A ton of solution per cubic foot of zinc per twenty-four hours is equivalent to forty-five minutes' contact, and yet so thoroughly may coatings preserve the zinc from actual contact with the solution that even this rate of flow may with weak solutions have to be diminished to secure good results. The use of lead salts in all dissolving solutions, besides the effect in assisting solution of the gold, apparently owes its advantage of maintaining lengthy efficiency of precipitation with weak solutions to the fact that deposition of lead on the zinc in the boxes enables fresh uncoated precipitating surfaces to be continually exposed. Similarly with cupriferous solutions, lead prevents the copper depositing as a smooth coherent metallic coating on the zinc, which otherwise would be thus shut out from contact with the solution. As might be expected on the assumption that the negative element merely forms a site for disengagement of hydrogen, there appears little difference in the efficiency of the freshly prepared metallic couples, zinc-lead, zinc-copper, zinc-mercury, etc., and advantages of one over the other depend on other considerations. Thus the zinc-mercury couple is brittle and crumbles in use, whilst the zinc-copper tends to yield base bullion. A mixture of lead and zinc shavings has a lengthy efficiency, possibly due to the fact that the zinc hydrate formed does not coat the whole couple to the same extent as with the usual lead-coated zinc shavings.

Hydrogen which has assumed the molecular condition and is visible in the liquid as bubbles is useless for precipitation purposes, the available energy for reduction having been degraded by the self-combination of the nascent atoms into molecules. A vigorous evolution of hydrogen bubbles in the precipitation boxes of any process indicates good precipitation merely since it shows that a corresponding amount of nascent hydrogen, portions of which perform work, is being generated.

Besides nascent hydrogen, however, one or two other means of precipitating gold are available. As chemical precipitants, $AgNO_3$, which forms the insoluble double gold-silver cyanide $AuAgCy_2$ (Crosse), and copper sulphate, reduced by $SO_2$ from the acidulated solution, which precipitates the gold as the double aurous-cuprous cyanide $Au_2Cu_2Cy_4$ (De Wilde) are rapidly and perfectly efficient.

It is stated that commercial calcium carbide and also phosphine precipitate gold from cyanide solutions. Any such action is probably due to the decomposition of water by substances with such a strong affinity for oxygen.

Many acids and salts effect partial precipitation of the gold in rich solutions, possibly by partly decomposing the potassic aurocyanide, with formation of the hypothetical $HAuCy_4$ which sets free insoluble $AuCy$ to some extent; thus, for example:

$$HCl + KAuCy_4 = KCl + HAuCy_4$$
$$2HAuCy_4 = H_2AuCy_5 + HCy \cdot AuCy$$

A current of $H_2S$, generated externally and passed through the acidulated auriferous cyanide solution, effects some precipitation. Metallic salts such as $FeCl_3$, $Co(NO_3)_2$, $Pb(NO_3)_2$, or $ZnCl_2$, even when added in excess to gold bearing cyanide solutions, have little precipitating effect when the original amount of gold in solution does not exceed a couple of dwts. per ton (3.4 mgrms. per litre). Oxidizing agents, such as excess of $KMnO_4$, $K_3FeCy_6$, or $HNO_3$, used with a view of decomposing by oxidation the soluble $KAuCy_2$ are of small efficiency on solutions low in gold, as also are reducing salts such as $FeSO_4$ or $SnCl_2$, or organic reducers such as formic aldehyde, glucose, glycerine and Fehling's solution. The powerful oxidizing effect, however, due to addition of sulphuric acid, and potassium bichromate to auriferous cyanide solution, seems to thoroughly break up the potassium aurocyanide and precipitate the gold.

The cleansing effect of acids on zinc has already been referred to, and hence it is reasonable that acidulated auriferous solutions, when brought in contact with any metal such as zinc or iron, should rapidly and completely deposit their gold, and this is actually the case.

Freshly burned charcoal acts for a time as an efficient precipitant of gold from cyanide solutions, apparently until the occluded hydrogen, which constitutes about 10 per cent of the gas condensed in the pores, becomes exhausted. It is probable that other materials containing occluded hydrogen would act in the same way.

In general, past experience shows that, apart from acidulated solutions and from processes where electric energy from an external source is made use of, research for a precipitating agent having the following properties would be on the right lines, namely, a body exposing a large amount of surface in proportion to its weight, which gradually dissolves in a solution containing cyanide and possibly some other neutral or alkaline substance compatible with cyanide, with ready evolution of nascent hydrogen. Applying these requisite conditions to filiform zinc or zinc couples and ordinary cyanide solutions, it will be seen that they are fulfilled to a great extent, the main objection being that a comparatively strong solution of costly KCy is required to obtain and maintain the highest possible precipitating efficiency.

The ideal method of precipitation is not only perfectly efficient, but fulfils all the following conditions: 1. It is independent of the cyanide strength of the solution. 2. It presents a large surface for joint contact of the precipitating agent and the molecules of an auriferous compound dissolved in the solution. 3. It concentrates continually the precipitated gold in a limited space. 4. Free cyanide contents of solution are not appreciably lessened by the operation of precipitation. 5. The solution after precipitation must not carry any compound which would interfere with its direct re-use after further addition of cyanide. 6. It allows of ready conversion of precipitated gold into bullion. 7. The apparatus employed must be cheap and simple to install and operate.

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Important Decision on Tesla Split-Phase Patents.—Judge Archbald, of the United States Circuit Court, Eastern District, Pa., has recently handed down a decision in the suit of the Westinghouse Electric & Manufacturing Co. against H. C. Roberts and Sangamo Electric Co., which has an important bearing upon alternating current meters and fan motors. The suit was under the so-called Tesla split phase patents. The defendants' device against which suit was brought was the Sangamo meter. The court decided that the complainants had satisfactorily proved that Tesla's date of invention preceded that of Farraris and others, and that the device in question was an infringement. Evidence was adduced by the Westinghouse Electric & Manufacturing Co., showing that Tesla's date of invention was several months prior to the Ferraris publication.

In view of the enormous commercial importance which the induction motor now has, the priority of its invention has long been a subject of extended discussion and litigation. It was invented in its principal features independently by Mr. Tesla in this country and by Prof. Ferraris in Italy, and from this invention dates one of the greatest advances made in alternating-current engineering.

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

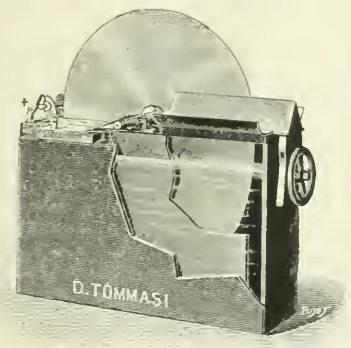
By Carl Hering.

*Congress of the Houille Blanche.*—In the London *Electrical Review*, September 4, appears the first part of an article, by Marcel Bloch, on the proceedings of the recent Congress of the "Houille Blanche" in France. The term "Houille Blanche," literally "white coal," was first applied in France to designate the motive power obtained from waterfalls. The interesting statement is made that the hydraulic energy of the Alps and the Pyrenees can be utilized to the extent of 10,000,000 hp, there being in use at present in France alone some 500,000 hp of this total. This figure already makes a difference in the consumption of coal in France, and the reserve remaining, it is estimated, will make an annual saving in France of some 200,000,000 of francs which is yearly paid for the importation of coal, amounting to some 13,370,000 tons, out of an annual consumption of 45,200,000 tons. The Congress was convened for the purpose of considering the best means for arriving at this desirable result, and dealt with the legislative, commercial and technical sides of the problem. The author refers to a paper by Picou, in which he drew attention to practical considerations which are to be taken into account in equipping a hydro-electric generating station. According to him there is a necessity of a closer co-operation of the electric and the hydraulic engineer in France for designing such stations. Electrical engineers are warned against too costly installations, by attempting to get exceedingly high efficiencies or too close regulation and costly construction of switchboards. Reference is made by the author more fully to a paper of Gall on the actual status of the electrochemical industries. The first part of the paper deals with the electrolysis of sodium chloride. The different processes for carrying out this electrolysis are touched upon and under the heading of mercury apparatus it is remarked that the Castner and Kellner apparatus is considered the best for this purpose, but although used largely in England and Germany, the Hulin process is better known in France. The latter employs molten lead for forming lead sodium compounds, which are further decomposed by steam. The more modern gravity cells, used in Germany, include neither diaphragm nor mercury, the caustic soda being obtained from electrolysis of sodium chloride solution, which separates it in the cells by means of the higher density of this product, in comparison with the sodium chloride solution. In the opinion of Mr. Gall it is certain that the apparatus now used for the preparation by electrolytic processes of caustic soda and chlorine are more economical than the old-fashioned processes of Leblanc and Solvay, especially when water power is available to give a cheap supply of energy. The output corresponds to a production of 1260 grams of caustic soda, and 1325 grams of chlorine, that is about 400 liters an hour, with a current of 1000 amperes and a maximum difference of potential of 5 volts, which represents an expenditure of 5½ hp per kilogram of soda per hour. He predicts a bright future for the industry, but thinks that on account of the limited demand for bleaching powder in France, a plant producing as much as 10,000 tons of caustic soda, which is not a great total, can hardly dispose of all its chlorine. Other applications of chlorine are being sought out; one of these which would appear to be very suitable, is to the production of tetrachloride of carbon, a liquid body containing 92 per cent of chlorine, with an agreeable odor, and possessing, like benzine and bisulphide of carbon, the property of dissolving fats, but with the advantage of being uninflammable and not forming explosive mixtures with the air. It is stated that on all sides this substance is being experimented with. The paper then touched upon the manufacture of alkaline hypochlorites, it being stated that Hermite's process is the best known. The current intensity is 1000 amperes to 1200 amperes, under a difference of potential of 5 volts; the paper manufacturers are said to be in favor of this process. The manufacture of chlorates is next touched upon, and it is stated that the works at Chedde have recently prepared, with the aid of special and perfected apparatus, an explosive powder, under the name of cheddite, superior to those now in existence. The author states that Mr. Gall laid great stress on the importance of the regulations concerning the production of electrochemical products, especially in regard to the tariffs for transport and the duties paid on them, to enable easy exportation of the material, without which the industry would never be able to exist in the face of foreign competition. Another paper by Boucher deals with the question of cleaning the water from the water courses, before utilizing it in the turbines.

*Tommasi's Apparatus for the Preparation of Spongy Lead.—In L'Industrie Electrochimique*, August, there is given an illustrated description of Tommasi's apparatus for the electrolytic preparation of spongy lead. It is reproduced in the adjoining figure and consists of a rectangular vat, filled with a solution of the double acetate of lead and sodium. A pair of anodes of lead are arranged, one on each side of a disk-shaped lead cathode, which can be rotated; only a segment of the latter dips into the electrolyte. As the disk rotates that part of it which emerges from the electrolyte passes between two scrapers, which are stated not only to serve the function of scraping the lead off, but also to depolarize the surface of the disk. The lead thus obtained represents a spongy mass, composed of a multitude of small crystals, and is said to be very suitable for storage batteries, and especially those of Tommasi's system. The cost of preparation of 1 ton of spongy lead is said to be 10 francs, which seems surprisingly low.

*Light Aluminium Alloys.*—Before the recent meeting of the American Society for Testing Materials, Prof. J. W. Richards read a paper on the above subject. He stated that for all purposes where the rolled, drawn or worked pure metal is sufficiently hard and strong, it is advisable to use the pure metal, as it resists alteration by the atmosphere and other corroding agencies better than almost any of its alloys, and better the purer it is. For cast articles and wire, rod or sheet, which are not sufficiently strong or hard when made of the pure metal, the aluminium can be alloyed with small quantities of other metals, which improve it in various ways without materially increasing its specific gravity. The best method of alloying the aluminium with other metals is taken up and described in detail, the use of a flux in melting not being recommended, as it attacks the crucible, and thus introduces impurities into the alloy. Almost all the light, strong alloys are stated to melt easier than aluminium, antimony, however, being an exception, as small quantities of it increase the melting point considerably. Thirty-three per cent of antimony makes an alloy which melts at 230 degrees higher than aluminium, and 250 degrees higher than antimony. As far as the specific gravity is concerned, the alloys with magnesium, 2 to 12 per cent, are the only ones which are lighter than aluminium. Theoretically, 10 per cent of magnesium would make a mixture which should have a specific gravity 0.16 less than aluminium, whereas it is actually 0.24 lighter. This points to expansion taking place during alloying. The molds for castings, the rolling and annealing, the dipping and frosting and the black finishing of the alloys are

then discussed. Prof. Richards then describes the alloys of aluminium with various metals, such as chromium, titanium, manganese, tin, silver, nickel, tungsten, copper, magnesium and zinc. He states that the chromium alloys are being used commercially at present, but that the use of the titanium alloys has practically disappeared, as they are easily corroded. The alloys of nickel with aluminium have not been found advantageous. The use of the magnesium alloys, such as magnalium, is said to be increasing in Europe, but no report of their durability is yet at hand. The Magnalium Gesellschaft, of Berlin, Germany, states that 61,000 lbs. per sq. in. may be obtained in chill castings. Cast in sand the




PREPARATION OF SPONGY LEAD

same alloy gives 21,400 lbs. per sq. in. The alloy contained 10 per cent of magnesium. Zinc is stated to be the cheapest, and, at the same time, one of the most efficient metals, which improves the mechanical qualities of aluminium. Up to 15 per cent the alloys are malleable, and in castings up to 33 per cent may be used. Casting in chills gives much better results than in sand. It is stated that a commercial alloy for making hard, strong and sharp castings consists of 15 per cent of zinc, 2 per cent of tin, 2 per cent of copper and 0.5 per cent each of manganese and iron. The paper is reprinted in *Metal Industry*, August.

*Recovery of Nickel from Scrap Anodes.*—The usual practice is to melt scrap nickel anodes in the crucible. Beckwith, at the recent Convention of the American Foundrymen in Milwaukee, gave an account of how a cupola was used for the purpose. As nickel is more infusible than iron, more coke is consumed, and the charges had to be made accordingly. A ratio of one to one was used for the bed, and two and one-half to one for the charges. The following is the result of one run, which required two heats, the total amount of scrap melted being 875 lbs. The scrap was worth $218.75, the coke used was 640 lbs., valued at $2.25; molder's time, $3; labor, $2, or total cost $226. The yield was 635 lbs. of nickel anodes which, at 50 cents a pound, made $317.50; then 75 lbs. scrap, worth $18.78, making a profit on the operation of $110.25.—*Metal Industry*, August.

### Theoretical and Experimental.

*Determination of the Electrochemical Equivalent of Silver.*—The most recent determinations of the electrochemical equivalent of silver, by Potier, and Pellat, and Paterson, and Guthe had given the value 0.011192. But experiments of Richards, Collins and Heimrod had led to the belief that this number was too high by about two thousandth (presumably meaning two parts in one thousand). Pellat and Leduc therefore determined to repeat the experiments, following the method used by Potier and Pellat with the following modifications. The voltameter was formed of a hemispherical silver dish, serving as cathode, and having a surplus of 500 sq. cm. It was filled with a normal solution of silver nitrate, neutral towards methylorange. The anode was formed of pure crystalline silver from previous electrolyses, which was contained in a sort of inversed receptacle, and separated from the bath by a sheet of paper between two layers of muslin. The anode surface was about 50 sq. cm., and the current about 1 ampere. The duration of the experiments was two to three hours, and the amount of silver deposited was 8.3 to 12.4 grams. The influence of the various sources of error, as the uncertainty of the beginning and the end of the experiment, the variation of the current, the errors of weighing, washing, etc., were thus considerably reduced. The Daniell cells were replaced by accumulators which gave a remarkably steady current. The circuit comprised a rheostat, an interruptor and a resistance $r$ of about 1.4 ohms, formed by a bare constantan wire dipped into a bath of petroleum. The difference of potential $r\,i$ at the terminals of this resistance was opposed to the electromotive force of a Latimer-Clark cell, and the equality was found by means of a capillary electrometer. The equilibrium was maintained during the whole experiment by very slight adjustments of the rheostat. The regulating period in the beginning did not occupy more than a fraction of a minute. In order to ascertain in absolute value the intensity of the current, the electromotive force of the Latimer-Clark cell was determined. For this purpose an absolute electrolynamometer was substituted for the voltameter, and the same Latimer-Clark was opposed to the difference of potential $IR$ produced at the ends of another resistance, $R$ of 48 ohms about, constituted exactly like the first one. The coefficient of variation of $E$ with the temperature was carefully determined, and found to be equal to 0.000845. The relation $R$ to $r$ of the resistances, was also carefully determined by many concordant observations. The coefficients of temperature variations of $R$ and $r$ were found very small. The time was measured by a very fine chronometer. All the weighings were corrected for air pressure, and the weights were compared with a gram weight from the International Bureau of Weights and Measures. The average of three well concordant experiments gave 0.011195, and the authors believe that it seems that the total systematic error cannot exceed one-half thousandth. The authors, therefore, consider it as certain that the mass of silver deposited by one coulomb under the above conditions is comprised between 1.119 mg. and 1.120 mg. The comparison of the resistance $R$ with a mercury ohm, placed in melting ice, has permitted the authors to deduce from the above determinations the absolute value of the electromotive force of the Latimer-Clark cell, which has been found to be 1.4334 volts at 15°. Another similar cell gave 1.4337 volts. Two Weston elements gave 1.0169 volts, and 1.0181 volts respectively, the values being expressed in international volts, derived from the international and the theoretical ohm. The paper was presented before the French Academy of Sciences, and is reprinted in *L'Industrie Electrique*, August 10.

*Rotation of Liquids in the Magnetic Field.*—Prof. Drude, the well-known physicist maintains that theoretically there can be no motion of a diffusing liquid, the diffusion of which takes place vertically to the lines of force of a magnetic field, if there is not generated at the same time an electric current in the liquid. Such a liquid, therefore, does not rotate in a magnetic field, the lines of force of which run radially-horizontally, if the liquid is arranged so that it is insulated, and the temperature of the diffusing layer is everywhere the same, so that no electric current can be generated. As the electromotive force between dilute and concentrated liquids, for instance, $H_2O$ and $H_2SO_4$, depends, as a rule, on the temperature, electric currents (thermo currents) must be generated, when the temperature of the diffusing layer is not constant, and as a consequence a rotation of the liquid in the magnetic field is produced. For instance, take the case of $H_2SO_4$ and $H_2O$ which are carefully super-

posed upon each other in a glass vessel ($H_2O$ above), so that a well defined horizontal diffusion layer is produced. If the rim of the vessel is heated up, say by a coil or a warm bath or a flame, thermo currents must be generated, which rise vertically at the rim of the vessel, flow horizontally for a little distance in the water, then descend vertically in the neighborhood of the center, and return again horizontally towards the rim. If, therefore, this glass vessel is introduced into a space filled with horizontal radial lines of force, directed towards the interior, the liquid seen from above must rotate at the rim in a clockwise direction, and counterclockwise in the center. Experiments which bear out this theory are described by Prof. Drude in the *Zeitsch. f. Elctrochem.*, August 13. In a crystallizing dish of 10 cm. diameter, $H_2SO_4$ and $H_2O$ were carefully superposed, and the dish was put upon the core of 10 cm. diameter of a large electromagnet, which served as the north pole. The south pole of the electromagnet was formed of a wrought-iron cylinder, 3.5 or 2.6 cm., in diameter, which was arranged $\frac{1}{2}$ cm. above the liquid. When the magnet was excited, a rotation of the liquid took place in one or more directions, according as to whether little or much $H_2O$ had been superimposed on the $H_2SO_4$. Evidently the initial conditions are very complicated, as considerable heat is generated by the diffusion of the $H_2O$ into the $H_2SO_4$, which heat will be less at the walls of the vessel on account of the cooling effect of the walls. The liquid must, therefore, rotate counter clockwise at the rim, and the experiment showed this to be the case. But if the rim was heated, the direction of rotation reversed, and finally the whole liquid rotated in the clockwise direction. This is explained by the shape of the magnetic field in this particular case, as the lines of force are vertical in the center, and their horizontal component is very much smaller there than at the rim, therefore the counter clockwise movement in the center, which is to be theoretically expected, does not take place. It was proved, experimentally, that the difference of temperature of the diffusing layer was determinative for the rotation of the liquid, by introducing a needle-shaped thermo-element into the diffusing layer. When the element was moved radially, temperature differences were found, which were parallel to the direction of rotation of the liquid at the same place. For instance, if the measurements were taken from the rim towards the center, and the indications of the thermo-element showed cold, warm, and cold again, the rotations at the same places were left hand, right hand and left hand again. If, finally, a unidirectional rotation had set in, after heating the rim of the vessel, the thermo-element always showed a constant decrease of temperature from the rim towards the center. The rotations which appear in the beginning without heating of the rim, soon disappear, evidently on account of the equalization of the differences of temperature in the diffusing layer; but if the rim is heated, rotation appears again, and always in the expected direction. Drude concludes that Urbasch's experiments, which were made without heating the liquid, only give favorable results in the case of $H_2SO_4$ and $H_2O$, on account of the considerable heat produced by the diffusion, with HCl and $H_2O$ in this case, the phenomenon manifests itself only to a very slight degree, and with $CuSO_4$ and $H_2O$ it does not appear at all. When the rim is heated, the rotation becomes very perceptible in the case of HCl and $H_2O$, but in an opposite direction to that of $H_2SO_4$ and $H_2O$. The thermo-electric current between the former combination is opposite to that between the latter. $CuSO_4$ and $H_2O$ showed very small thermo-electric currents, and, therefore, a sensible rotation could not be obtained, even when the rim of the vessel was heated. The experiments do not succeed if the upper pole is not situated above the liquid, but dips into it, and is kept from coming into contact with it by a glass cover. In that case the central parts of the liquid are also cooled off, the same as the layer around the rim.

*Electrolytic Separation.*—Methods for the electro-analytical separation of manganese from iron; aluminium from iron and nickel; and zinc from iron, are described by Hollard and Bertiaux in *Comptes Rendues*, t. 136, pages 1266-1268, and reprinted in *L'Eclairage Electrique*, June 27. The separation of manganese from iron is one of the most difficult problems of electro-analysis, but, at the same time, a most desirable one, as it enables one to determine both metals at the same time. Manganese, as is well known, is one of the few metals which separate under ordinary conditions as peroxide on the anode, while the iron goes to the cathode. The method which the two authors propose depends upon the addition of sulphurous acid to the electrolyte. The electrolyte is made by adding to a solution of the sulphates of iron and manganese, which may contain a few drops of free sulphuric acid, 5 grams of citric acid, 25 to 50 cc. (according to the quantity of iron present) of a saturated solution of $SO_2$, and 25 cc. of ammonia of 22° B. It is neutralized by adding sulphuric acid and then made alkaline again with a few cc. of ammonia. The iron is deposited on a platinum cathode with large surface, the anode is a platinum spiral of small surface. Electrolysis is conducted at a temperature of 48°, with a current of one ampere, the volume of the solution being 300 cc. With a suitable proportion of sulphurous acid, the iron is deposited completely on the cathode before the manganese comes down on the anode. The solution is then poured off, the deposit dissolved in 1-5 sulphuric acid and titrated with the usual precautions with permanganate. In order to precipitate the manganese, the solution is again electrolyzed with a platinum anode of large surface, and a small spiral cathode. The temperature of the bath must be between 90 and 95° C., and the current one ampere. The excess of $SO_2$ is soon oxidized, and the manganese is deposited at the anode, the operation being complete at the end of several hours. The manganese is determined volumetrically, by adding hydrochloric acid, potassium iodide and carbon bisulphide. The chlorine set free by the $MnO_2$ liberates iodine, which dissolves in the carbon bisulphide. The latter is then titrated with hyposulphite until the bisulphide of carbon is no longer colored pink. The separation of iron and aluminium has been effected by the authors in an analogous way. The metals, in the condition of sulphates, are electrolyzed with the addition of ammonium citrate and sulphurous acid under the same conditions as above. It is said that the effect of the $SO_2$ is, first, to prevent, during electrolysis, the precipitation of alumina, which might carry some iron with it, and, secondly, the precipitation of iron as basic salts. The separation of iron and zinc has been accomplished in a similar manner with the help of sulphurous acid, the iron being brought into the condition of ferrocyanide of potassium. The solution of zinc and iron, as sulphates, was treated with 25 to 50 cc. of sulphurous acid (according to the quantity of iron present), and nearly neutralized with soda; 15 cc. of potassium cyanide of 20 per cent were then added and, after this, 50 cc. of soda of 15° B. The solution was diluted to 300 cc., and electrolysis carried out in the cold with a current of 0.3 ampere. The zinc, under these conditions, comes down alone, and the iron stays in solution.

*Electrolytic Reduction of Unsaturated Acids.*—Prof. C. Marie describes, in *Comptes Rendues*, for the meeting of June 2, 1903, reprinted in *L'Electrochimie*, July, a series of experiments, which he conducted, in order to find out whether an absorption of hydrogen could be brought about at the cathode, in the electrolysis of unsaturated organic acids, in order to change them into the corresponding saturated acids. He experimented with aconitic acid, which he wanted to convert into tricarballylic acid. Electrolysis was conducted with different metallic cathodes: with platinum, copper and lead no reduction worth mentioning was obtained. It was necessary to use mercury as cathode, in order to succeed. The experiments were conducted in the following manner. The solution of aconitic acid, half neutralized with soda, is put into a cooled vessel, the bottom of which is covered with mercury, which

serves as cathode. The anode is constituted by a small strip of platinum. The cathodic current density is about 2 amperes per sq. dm. The absorption of the hydrogen is not complete, even in the beginning; there is always a certain amount liberated as such, and, therefore, about twice the theoretically-calculated quantity of current is necessary. The solution is then neutralized by soda, and the resulting tricarballylic acid is separated by copper acetate or nitrate, the copper tricarballylate being insoluble in the solution, which is slightly acid from acetic acid, while the copper aconitate is soluble. After the decomposition of the salt by $H_2S$, the acid is obtained with a yield of about 60 per cent. The loss is caused by the anodic destruction of the product with the formation of $CO_2$ and of unsaturated compounds of a disagreeable odor. The destruction is considerably increased when the operation is conducted at elevated temperature or in alkaline solution. On the contrary, the oxidation is nearly annulled if a more stable unsaturated acid is taken; for instance, cinnamic acid. The electrolysis of this acid, under the above conditions, gives hydrocinnamic acid in nearly quantitative yield.

*Active and Inactive State of Two Identical Carbon Electrodes in Fused Electrolytes.*—The observation that two carbons which, in molten calcium chloride, showed a difference of potential, though they had not been connected to a source of current, led J. Hardin to investigate this phenomenon. His results are published in the *Phys. Zeitsch.*, July 15. He thought, in the beginning, that a difference in the electrodes might give rise to the production of thermo-electric currents, but the difference of potential observed seemed too large to be explained in that way. The experiment was then carried out in the following manner. A carbon rod of 5 mm. thickness, 350 mm. long, made from carbon as pure as possible, was first heated in an electrically-heated carbon tube up to 1800°, to drive out any impurities. The rod was then cut in the middle and fixed in a support in such a way that the cut surfaces could be pressed against each other by screws. The outer ends of the rods were connected with a millivoltmeter. The ends which pressed against each other were then brought to a strong, high, white heat by a blast lamp, but the highest obtainable deflection was only 5.5 millivolts. Chloride of calcium was then heated up in a porcelain crucible, and the above electrodes introduced. As soon as the salt began to melt, the galvanometer showed a deflection toward the right and again toward the left; this vaccillation showed itself every time when fresh electrodes were introduced, even when the melt was already fluid. After a short time, however, there manifested itself a steady activity of one electrode, producing a continuous deflection toward one side. The difference of potential increased to a certain point with increasing temperature; after the latter had been overstepped, the potential decreased again. This point was at 650° C. with calcium chloride, and the difference of potential was 0.15 volts. The polarization was so great, however, that if an instrument with only 10 ohms resistance was used, the potential dropped immediately, and it did not make any difference, in this case, whether a larger or a smaller piece of the electrodes dipped into the melt. The indications of the galvanometer were not changed, whether the electrodes were protected from the air during the experiment or not. The phenomenon showed itself not only with calcium chloride, but also, though in a lesser degree, with calcium nitrate. The melting temperature of the salt is not the determining factor for the difference of potential, for if the electrolyte was molten-lead chloride a potential of 0.35 volts was observed, while the temperature was only about 300° C. A mixture of sodium and potassium carbonate gave about 0.04 volts. The distribution of the temperature seems to play an important role, for the amount of the difference of potential varied considerably if the crucible was heated on one side only. The curious fact was, however, established that the activity was greatest at that electrode which had the lowest temperature. If one or the other side of the crucible was heated alternately, the direction of the current was often reversed, but this did not take place with regularity. The author thinks that when chloride of calcium, for instance, into which two carbon rods are dipped, is heated, a chemical reaction takes place in such a way that the carbon combines with the chlorine. On account of the difference of temperature, one electrode is then enabled to take more chlorine ions than the other, which would explain the difference of potential. The fact that the two electrodes were attacked, but one more than the other, seems to him to bear out this opinion.

*Silicides of Chromium.*—To the three silicides of chromium, which had been described up to the present, namely, $SiCr_4$, $SiCr_2$ and $Si_2Cr$, there is now added a fourth one, $Si_3Cr_5$, another product of the electric furnace. The method of preparation of the latter is described by its discoverers, Lebeau and Figueras, in *Comptes Rendues*, séance du 2 Juin, reprinted in *L'Electrochimie*, July. It is obtained by heating, in the Moissan furnace, in a carbon crucible, a mixture of 100 grams of silicide of copper of 12 per cent. with 4 grams of chromium. The time of heating must be four minutes, with a current of 600 amperes at 70 volts. The resulting regulus must have about the theoretical weight. It is pulverized and extracted with dilute nitric acid, alternately with dilute commercial caustic soda, until the action of the two reagents ceases. The silicide, $Si_3Cr_5$, crystallizes in long quadrangular prisms. Its density is 5.6 at 0°. It scratches glass, but not quartz. Chlorine reacts with it with incandescence at about 400°, giving chlorides of chromium and silicon, bromine attacks it more slowly at a cherry-red heat, and iodine under the same condition has no action. It is unoxidizable in dry or moist air in the cold. Hydrochloric acid gas decomposes it with the production of chromous chloride. Dilute cold hydrochloric acid does not act on it, but the concentrated acid dissolves it very easily, if heated a little; nitric and sulphuric acid do not act upon it, but hydrofluoric acid attacks it in a few moments. The nitrate and chlorate of potassium in a fused state, which react energetically with the carbides of chromium, do not change the silicide, but with the alkaline carbonates it transforms itself rapidly into silicate and oxide of chromium. If a nitrate is added, a mixture of silicate and alkali chromate is formed.

*Silicide of Ruthenium.*—Moissan and Manchot describe in Comptes Rendues, vol 137, p. 229, the preparation and the properties of a silicide of ruthenium. If a mixture of 1.5 grams of powdered ruthenium and 7 grams of crystallized silicon is put into a carbon boat in the middle of a tube of the same substance, the mixture rapidly fuses, and the combination takes place. The latter is accompanied by a rapid disengagement of vapors, after which the liquid becomes quiet again, and the experiment is finished. Two or three minutes are required, with a current of 600 amperes, at 120 volts. At the moment of combination a certain quantity of the metal volatilises in the form of a brown vapor. It is important that the current of the electric furnace should be very constant, otherwise the results are not comparable. Under these conditions a well fused regulus is obtained, which is pulverized, and first treated on the water bath with a solution of caustic soda, and then with a mixture of hydrofluoric and nitric acids. The residue consists of brilliant white crystals, mixed with variable quantities of carborundum, which can be separated from them owing to the difference of specific gravity, by methyl iodide, in which one floats and the other sinks. The same compound can be obtained in a state of greater purity, by heating in the electric furnace, in a carbon crucible, a mixture of 1.5 grams of ruthenium, 15 grams silicon and 5 grams of copper. The reaction takes place with more regularity at the boiling temperature of the silicide of copper, and after the same treatment as above, there is obtained a very well crystallized silicide of ruthenium, corresponding to the formula $Ru\,Si$, and free from carborundum. The yield is about 80 per cent of the weight of ruthenium

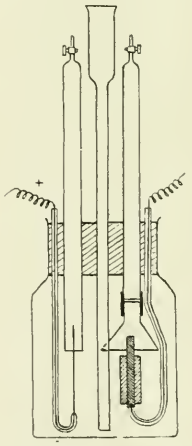
taken. The properties and the method of analysis of this new compound are also described.

*Double Carbide of Chromium and Tungsten.*—Up to the present time only very few double metallic carbides were known, as, for instance, those of iron and tungsten, iron and chromium, iron and manganese, etc. Moissan and Kouznetzow, in *L'Eclairage Electrique*, August 22, describe the preparation of a new double carbide, that of chromium and tungsten, in the electric furnace. In order to prepare it, a mixture of 100 grams of sesquioxyde of chromium, 45 grams of tungstic acid and 30 grams of petroleum coke or sugar carbon, are heated in the electric furnace, in a carbon crucible for about five minutes. It is important not to use a current of too high intensity, 400 amperes, at 75 volts, being sufficient. A homogenous regulus of metallic appearance is obtained, which is pulverized and treated with hot hydrochloric acid. Then follows a treatment with concentrated ammonia, to dissolve the particles of tungstic acid which are inclosed. The residual powder is washed with water and dried. The double carbide can also be prepared by another method. A mixture of chromium and metallic tungsten, with an addition of a small quantity of sugar carbon in presence of a great excess of copper, is fused in the electric furnace, avoiding as much as possible the carbon vapors of the arc. The proportions are: Tungsten, 7.5 grams, chromium, 10 grams, carbon, 0.2 grams, and copper, 150 grams. The mixture is fused rapidly in a carbon crucible, and the copper is maintained in ebullition for 1 or 2 minutes. After cooling, a metallic homogeneous regulus remains in the crucible, which is treated with nitric acid. The residue consists of small crystalline crusts, of metallic aspect, which are represented by the formula, $W_2C$, $3Cr_3C_2$.

*Specific Resistance of Non-Metallic Conductors of the First Class.*—In the *Zeitsch. f. Electrochem.*, August 13 Ferchland gives the results of his measurements of the specific resistance of peroxide of lead under compression. He obtained his material by electrodeposition from a 25 per cent lead nitrate solution, which was kept neutral by the continuous addition of lead oxide or carbonate. With a suitable current density at the anode, of 5 amperes per sq. dm., there was obtained a deposit of almost black color, perfectly dense, and having a glassy lustre. It was very strong, and so hard that it was not attacked by emery. The chemical composition did not correspond exactly to the formula $PbO_2$, but was very constant, showing about 1.5 per cent of water. The material was obtained in cylinders of 0.35 to 0.36 cm. diameter, and 1 to 6 cm. length, with a hole in the center. A difficulty was found in getting good contacts, until the author utilized the idea of introducing the peroxide rods in a machinist's die tap, for cutting screws. They were insulated from the tap, and the screw of the latter tightened more and more, until the resistance of the lead peroxide rods did not further decrease, or until they broke. The measurement of the resistance was carried out with a universal bridge and a very sensitive galvanometer as zero instrument. The results of the decrease of the resistance with increasing pressure are given. The spec. resistance, in terms of the meter, square millimeter unit, was found to be 29.9 ohms in one case, and 37 ohms in another. The results show a variation from those obtained by Streintz from the compression of powders, being about 13 to 16 times greater. The author attributes this to possible variations in the composition of the electrolytically deposited peroxide of lead owing to differences in the amount of water contained in it. He calls attention to the considerable effect of even the smallest impurities of a body on its conductivity.

### Primary and Secondary Batteries.

*Peroxide of Manganese Briquettes and Cylinders.*—The manganese peroxide briquettes and cylinders for Leclanche cells are very unequal in their qualities. They are manufactured usually by compression of the mixture of the different materials at somewhat elevated temperature, about 100° C. Dr. J. Zellner gives the analysis of several of them in an article on the above subject in the *Centralblatt f. Acc. Elem. u. Automobilenkunde*, July 15, and August 15. He shows further, that the calcination of the briquettes is absolutely senseless, by citing the case of a mixture consisting of retort graphite, 41.67 per cent; peroxide of manganese, 41.67 per cent (of 73.86 $MnO_2$); tar, 16.66 per cent. The amount of peroxide of manganese was, therefore, 30.8 per cent. After calcination, the mixture should contain 34.6 per cent of peroxide of manganese, assuming that about one-third of the tar remains in the form of carbon. The analysis, however, only showed 14.59 per cent; consequently, more than half the peroxide had become inactive. The author gives as the reason for the fact that so many calcined briquettes appear in the trade that the manufacture of briquettes is often in the hands of people with insufficient knowledge of chemistry. It is also stated, as an excuse, that the peroxide briquettes thus manufactured regenerate themselves in the air, which evidently means that the lower manganese oxide changes partly into the three-four oxide. The author gives the results of experiments which he made on this question, which showed that the manganous oxide, in moderately damp air, hardly oxidizes at all and, therefore, the above regeneration of the briquettes amounts to practically nothing. There is also usually entirely too much peroxide of manganese in such briquettes; as, after a good many years, during which time the zinc rods had been frequently renewed, the average peroxide content was still 80 per cent. As to the most efficient form of using the peroxide of manganese, the author thinks that the best way is to surround the battery carbons by compression with a mixture of finely-powdered peroxide and finely-powdered carbon (graphite). The use of good conducting carbon, for instance, pure graphite and as strong compression as possible will favorably influence the conductivity. Briquettes are best used in the form of thin plates, arranged close to the carbon. The author then gives the method of analysis of the carbon-manganese peroxide briquettes. The analysis, however, is not the only factor for a determination of the quality of a manganese peroxide body, as the depolarising action depends not only on the quantity and quality of the peroxide, but also on the thickness of the grain, the quality of the carbon and the porosity. The author uses the apparatus illustrated in the above figure, for the determination of the quality of a briquette. It consists essentially of a glass jar, closed by a cork stopper, with five perforations. Two measuring tubes provided with stopcocks are introduced through two of these openings, the lower end of one of the tubes being formed by a funnel, so as to catch all the gas which is generated at the peroxide briquette. The middle perforation receives a rather large funnel tube, and through the last two pass the platinum wires for the electric current, enclosed in glass tubes. The positive pole is formed by one of the platinum wires, while the briquette to be tested is connected with the negative wire. The vessel and the measuring tubes are filled with a pretty concentrated solution of sulphate of ammonia. A current of 0.1 to 0.2 amperes from two storage bat-




DETERMINATION OF THE QUALITY OF MANGANESE BRIQUETTES.

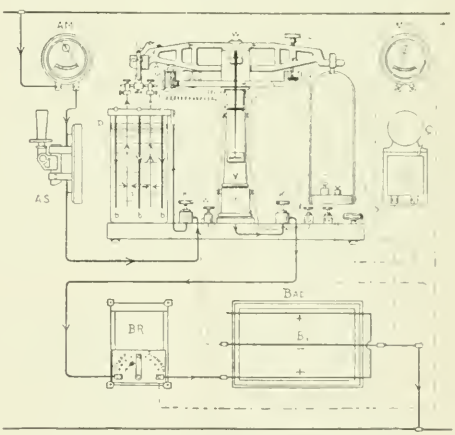
tery cells is conducted through the apparatus, and the time is noted when hydrogen begins to appear at the negative pole. The position of the liquid in the measuring tubes is then read off, the height of the liquid in the funnel tube above the level in the measuring tubes is measured with a millimeter scale, and the current is sent through the apparatus for a measured time. Then the gas volumes are read off, the differences of the levels between the funnel tube and the measuring tubes are read, the gas volumes are reduced to equal pressures, and the depolarising effect of the manganese peroxide body is calculated from the deficiency of hydrogen.

*Accumulator "Max."—L'Elettricista,* of August 1, contains a description of the accumulator "Max," which is stated to have been tried, with favorable results, by the French navy department. It consists of a number of electrodes, each of which has a central core of rolled antimonial lead wire, which is surrounded by a layer of active material about 3 mm. thick. The active mass is brought upon the electrodes under considerable pressure. A table gives the principal characteristics of the accumulator.

*Conversion of Persulphuric Acid into Caro Acid.*—In the course of experiments on the phenomena which take place in the charging of storage batteries, Mugdan endeavored to find an answer to the question whether in the electrolysis of sulphuric acid there are formed at a platinum anode other oxidising bodies in appreciable quantity besides the primarily-formed persulphuric acid and the caro acid which is formed from the latter. The caro acid can be determined by its oxidising action on KI, while the total amount of both acids can be determined by their oxydising action on Fe $SO_4$. The above question was sought to be solved by measuring the speed of conversion of one acid into the other, in order to find out whether a speed-constant could be found. The establishment of such a constant would at least make it probable that only these two oxidising bodies appear in the anode compartment, when sulphuric acid is electrolysed. The author found in the anode compartment of fresh acid, electrolysed with good cooling, only traces of the substance acting on KI; this is, therefore, only formed secondarily. With regard to this, an exact constancy of the speed coefficient would prove that primarily only one oxidising substance, namely, persulphuric acid, is formed, because in the other case a proportionality between the quantity changing in the unit of time to the quantity present would not appear. The expression for the monomolecular reaction was found nearly constant, but the measurements could not be carried out with sufficient exactness to draw the above conclusion. The experiments were carried out by electrolysing sulphuric acid of about 40 per cent, with varying current densities of 2 amperes to 4 amperes per sq. cm The electrolyte was cooled, and a diaphragm previously extracted with acid was employed. The time of electrolysis was about two hours. The anodic liquid, after dilution, was brought into a thermostat of 25°, and samples taken from time to time and titrated. The caro acid was determined in a sample taken at the same time, after strongly diluting it with ice water, and adding KI, by titration with thiosulphate without the use of starch. The experiments were always carried out with a great excess of acid, so that the change of acidity due to the reaction could be neglected. The second part of the article, in the *Zeitsch. f. Electrochem.*, August 27, in which the author gives the results of his experiments, is devoted to an investigation to establish the formula of the caro acid. The formula has been given as $H_2S_2O_8$ and $H_2SO_5$. The reaction between caro acid and KI is either: $H_2SO_5 + 2KI = K_2SO_4 + 2I + H_2O$; or $H_2S_2O_8 + 4KI = 2K_2SO_4 + 4I + H_2O$. In the first case the relation of the liberated iodine to the decrease of acidity is as 1 to 1, in the second case as 2 to 1. The author found in a series of experiments the relation nearly as 2 to 1, and considers, therefore, the formula $H_2S_2O_8$ as the most probable.

## General and Miscellaneous.

*Voltametric Balance.*—The voltametric balance of Dr. Pfannhauser serves to determine the weight of electrolytic metal deposits during the process of electroplating. The instrument acts thus as an ampere hour meter, and the thickness of the metallic deposit can be very closely regulated, as the process is automatically interrupted when the desired thickness of the deposit is obtained. Several improvements, in the form of the balance, as described previously, are given by the inventor in *Zeitsch. f. Electrochem.*, August 13. The general arrangement of the balance is shown in the figure below. The improvement consists in the arrangement of an electromagnet *M*, below an iron contact *A* on the beam of the balance. A spring *F* is also situated on the beam, which, when the cathodes *a* of the voltameter *P* have received their predetermined weight of deposit, touches a contact *S*. By this means a shunt current is closed, which energizes the magnet *M*. This attracts then the pole piece *a* in the beam of the balance, with the result that the beam is quickly pulled down, and the contact between a set screw *C* and a layer of mercury *N* on the other arm of the balance, is broken abruptly. The breaking of this contact interrupts the circuit of the plating




VOLTAMETRIC BALANCE.

bath. By this means it is made possible to interrupt the plating current at the exact time the predetermined amount of deposit is obtained, while with the former arrangement, when the set screw and the mercury vessel only were depended upon to break the bath circuit, errors of 5 per cent to 6 per cent of the total weight of the deposit occurred, as the break did not take place with sufficient accuracy. At the same time that the bath circuit is broken, a bell G" rings to advise the attendant. The manipulation and regulation of the balance is described in detail.

*Dryers and Drying Out for Electroplating Purposes.*—Under this title F. P. Davis, in *Metal Industry*, August, gives the results of his observations and experiences on the proper construction of drying apparatus for drying materials, which have been electroplated. He illustrates and describes in detail the arrangement of such an apparatus. Attention is drawn to the fact that too little consideration is usually given to the sawdust that is used for drying out, and the author discusses that question. According to him, for brass work after acid dipping, nickel work to be buffed, and the coarser grades of plated work, whitewood sawdust is very good. The sawdust should be from well seasoned lumber. "Gray" or "white" nickeled work, as it is variously designated, that is, work that is acid dipped or polished by attrition in a tumbling barrel, and plated with no further finish, is stated

to require much care in drying to retain its clear, light color. The essential point is said to be often overlooked, namely, that the work should be taken from the cold rinsing water directly to the dryer, and in no case should hot rinsing water be added, as the latter will invariably darken the work and turn it yellow. The dryer must be hot, and the work stirred about and agitated until dry, and then immediately removed, as any unnecessary heating will cause discoloration. The author states that small brass-plated articles and goods that are coppered merely to give color, and that are to be lacquered, with no further finish after plating, should always be dried without the use of hot water. The drying of plated work which is to be buffed after plating, will be greatly facilitated by rinsing a few seconds in hot, soapy water, and then passing it through clean, hot water. The brilliancy of articles which have been plated with just enough silver to whiten them is stated to be greatly increased if this process is used. The author thinks that it is small matters of detail like these that are worthy of attention, inasmuch as they help towards perfect work.

*Soldering of Aluminium to Steel and Iron.*—A note from the *Oester. Zeitsch. f. Berg. u. Hucttenwesen*, reprinted in *Chemische Zeitschrift*, September 1, on a new method for the above purpose. The method consists mainly in covering the iron pieces electrolytically with a layer of copper, and then pouring aluminium on them, which unites homogeneously with the copper. In this manner tubes or cylinders of cast iron, steel or wrought iron can be made with aluminium bosses. The iron parts which are to be treated are cleaned with caustic potash, and then connected as cathodes in an electrolytic vessel, filled with acidified ammonium oxalate solution; the anodes are sheets of copper. After a thin layer of copper has been deposited on the material, it is taken out and brought into an ordinary acid galvanoplastic bath, made up with copper sulphate and sulphuric acid, where it stays until the desired thickness of the copper is obtained. The material is then dried in an atmosphere as little oxidising as possible, and put into a suitable mold, into which the aluminium, heated to a cherry-red temperature, is poured. On account of the great affinity between copper and aluminium the metals unite readily, and the soldering is stated to be effected in a most satisfactory manner.

*Thermochemistry in 1902 to the Middle of 1903.*—In the *Chemische Zeitschrift*, September 1, Prof Cohen gives a short review of the work done in this field during the above time. Among others, he refers to the work of T. W. Richards, who showed that the thermochemical data, as given usually, contain certain errors, due to the neglect of the fact that the specific heats of reacting systems are changing during the reaction, and advocated the recalculation of all thermochemical data for a predetermined temperature (as, for instance, 20°), and to use the exact atomic weight numbers for O = 16.

*Physico-Chemical Institute of the University of Freiburg.*—*The Zeitsch. f. Electrochem.* June 11, contains the description of the new institute, by the director, Dr. G. Meyer. Current for electrochemical purposes is furnished by the street current of 2 x 220 volts. Two storage batteries are provided, one of 144, and another of 12 cells. The first battery is charged directly from the street mains with 440 volts, and is discharged in four or eight groups in parallel, with 72 or 36 volts. It has such capacity, that with one hour discharge at these voltages, currents of 300 or 600 amperes can be furnished. Lines for 50 amperes maximum run to the laboratory rooms, and 300 amperes maximum to the lecture room. A room for high-temperature electrochemical experiments is situated close to the battery, in which current up to 600 amperes can be obtained. With the help of the batteries, potentials of 72, 36, 24 and 8 volts are available, also 220 volts everywhere from the lighting circuit, and at three places provision is made for taking off 440 volts. A short description is given of the outfit for the electrochemical laboratory and for the lecture room.

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

Electric Furnaces and Furnace Products.

*Electric Furnace or Oven.* A. Eimer, New York. Patent 736,509. August 18, 1903. Application filed May 22, 1903.

The invention relates to a furnace in which small articles, as artificial teeth, chemists' crucibles, etc., may be heated. The furnace is constructed in a shape similar to that of a muffle, and the heating is accomplished by a resistance conductor, i. i. platinum wire. The heating member of the furnace is represented by a plate of refractory material, provided on its upper surface with a series of grooves or channels, in which the conductor is placed, and adapted to slide within the furnace upon the base-plate. Provision is also made for heating the upper part of the furnace. Various modifications in the disposition of the current-carrying conductor within the base-plate are also described.

*Electric Sectional Furnace.* August Eimer, New York. Patent 736,917, August 18, 1903. Application filed May 28, 1903.

The specification describes a furnace of the resistance-heating type, primarily intended for laboratory purposes. The furnace consists essentially of a trough-shaped receptacle of refractory material, which forms the bottom and the side walls. The roof of the furnace is represented by an independent cover of refractory material provided with observation apertures. The furnace is built up of a series of independent sections, and the connections are so arranged that either of the sections can be used by itself, or they may be connected in series, or in multiple. The heating is accomplished by radiation from a resistance conductor, which is embedded within the walls of the furnace, near its inner surface. Suitable provision is made to prevent loss of heat by radiation, and the connections are so arranged that the changes in the connections can be carried out quickly and conveniently.

*Apparatus for the Electrolysis of Fused Substances.* C. W. Roepper, Philadelphia. Patent 736,020, August 11, 1903. Application filed September 27, 1898.

The specification describes and illustrates several constructive forms of apparatus for the electrolysis of fused substances, which are designed primarily with a view of providing means for easily accomplishing the removal and renewal of that part of the apparatus, which is exposed to the action of the heating flame, where the apparatus is heated externally. In the constructions shown heat is applied to the bottom of the apparatus and the latter is constructed of a plate of various forms, suitable for particular purposes, which is made entirely independent of the rest of the furnace. The joint between this bottom plate and the furnace walls is kept tight by a cooling arrangement. When this bottom plate burns through, or shows signs of weakness, it can easily be removed and another one substituted for it.

*Process of Producing Chlorides of Corbon.* F. J. Machalske, Chicago. Patent 737,123, August 25, 1903. Application filed September 24, 1902.

The process consists in introducing a mixture of dry broken

coke, sodium chloride and pure silica sand into an electric furnace, consisting of a stack of firebrick with a magnesia lining, 2 carbon electrodes being introduced adjustably through the sides. An outlet flue for the chlorides of carbon is provided at the top, and a tap-hole is arranged at the bottom. The charge surrounds the electrodes, and the electric current passing between the latter heats it to a temperature sufficient to effect the reaction. The charge employed differs entirely from that used for the production of silicon carbide, where a small amount of sodium chloride is also usually added as a flux, in as much as the chlorine compound is used in much larger proportions. The temperature required is also lower than that necessary for the production of silicon carbide, as it is below 2000° C. The inventor states that it is probable, that at the high temperature the sodium chloride is first melted, and that the silica then reacts with the molten chloride to liberate chlorine, which in its turn combines with the incandescent coke to produce the chloride of carbon. The resulting chloride passes through a reflux condenser and the molten residue is drawn off through the tapping hole. Various chlorides of carbon may be produced by varying the proportions of the constituents of the charge, a typical reaction being $6NaCl + 2SiO_2 + 4C = C_2Cl_4 + C_2Cl_2 + [Si(ONa)_4 + Na_2Si]$. Sulphur chloride may be produced simultaneously with the carbon chlorides by adding sulphur to the charge, the reaction proceeding according to the equation, $6NaCl + 2SiO_2 + C + 2S = CCl_4 + S_2Cl_2 + [Si(ONa)_4 + Na_2Si]$.

### Apparatus and Processes for the Electrolytic Production of Metals and Compounds.

*Electrolytic Apparatus.* L. P. Burrows, Washington, D. C. Patent 737,554. August 25, 1903. Application filed January 22, 1902.

This apparatus is especially intended for the treatment of ores. It consists of a series of vessels arranged in cascade form, the upper one of which acts as a receiving and dissolving vessel for the ore. From there the latter passes into one of a series of filtering vessels, and thence into a receiving trough, which delivers it to the vessels in which the electrolysis of the solution obtained from the ore takes place. The ore is fed in a continuous stream into the receiving vessel, which is provided with a stirrer of peculiar construction, so arranged that the ore and any solvent which may be introduced into the vessel are brought into intimate contact. The stirrer is connected to the positive terminal of a source of electricity of a suitably high voltage, as, for instance, a dynamo of 110 volts. The ore pulp which is fed into the vessel, preferably contains sodium chloride or another electrolyte capable of furnishing a solvent anion. The oxygen and the chlorine liberated on the surfaces of the stirrer are stated to effect the rapid solution of any metal values contained in the ore pulp. The solution and the undissolved particles of the ore then pass in a full stream into one of the filtering vessels, and this stream serves as a path for the current from the solution in the dissolving vessel to that in the filter. Similarly the outlet stream from the filtering vessel carries the current into the receiving trough, and a stream from this trough carries it into the vessel in which deposition takes place. This vessel contains a ring-shaped cathode, which is connected with the negative terminal of the source of electricity. Wires also lead from one vessel to the other to act as safeguards and prevent interruption of the current in case the liquid connection should be broken. These wires are preferably insulated, except at their ends, which are in electrical contact with any solution remaining in the lower part of each vessel. The inventor states that the electric current not only serves to effect solution of the metals in the dissolving vessel and redeposition of these metals upon the cathodes, but also keeps all portions of the solution, whether in the several vessels or flowing through the connecting pipes and hoses, at a high temperature. The inventor does not disclose of what material this anodic stirrer is made, beyond saying that it is of metal. It would be interesting to know what material he has found to resist the action of the chlorine under these circumstances.

*Electrolytic Apparatus.* G. Bell and G. W. Bell, of Liverpool, England. Patent 737,560. September 1, 1903. Application filed June 18, 1901.

The apparatus described in the specification is primarily intended for the electrolysis of sodium chloride for the production of caustic soda and chlorine, and belongs to the mercury type of apparatus. The distinctive feature of the apparatus is contained in the fact that the transference of the sodium mer

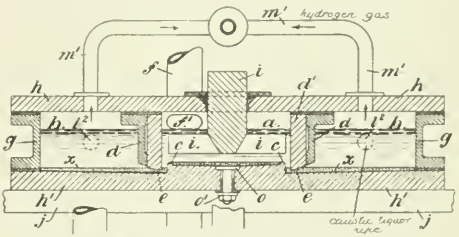



FIG. 1. BELL MERCURY CATHODE BELL.

cury amalgam from the compartment where it is charged into the compartment where it is to be discharged, is effected by means of the pressure exerted by the hydrogen, which is evolved in the discharge compartment. The apparatus is shown in cross-section in Fig. 1. In appearance it is much like a Castner apparatus, with its middle compartment *a*, however, serving as electrolytic compartment, while the discharge of the amalgam takes place in the two outer compartments *b*. The bottom of the middle compartment is raised above that of the outer compartments, and is so constructed that there is always a layer of mercury remaining on the bottom of the compartment in order not to interrupt the current. The move-

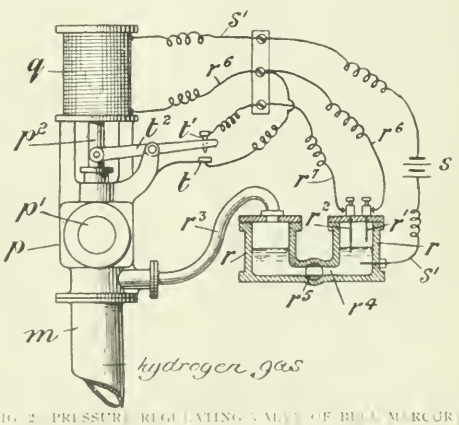



FIG. 2. PRESSURE REGULATING VALVE OF BELL MERCURY CATHODE BELL.

ment of the mercury to and from the electrolytic and discharge compartments is controlled by a valve on the upper end of the main hydrogen pipe *m*. When this valve is closed, the hydrogen generated by the discharge of the amalgam in the compartments *b* accumulates and its pressure gradually rises, until it has reached such height that it forces the mercury *x* from the bottom of the compartments through the passage *r* into the electrolytic compartment. While there, it receives a fresh charge of sodium, and after it is sufficiently charged the valve is opened, the pressure falls and the amalgam flows by gravity into the discharge compartments, where

the same cycle of operations is repeated again. The anode *i* consists of a vertical trunk, passing through the cover *h* and having horizontal bars projecting on either side from its lower end. The connection with the negative terminal of the current is made by a cathode plate *o* introduced into the electrolytic compartment through the bottom; $f^1$ is a pipe which serves to carry away the chlorine. The pressure regulating valve is actuated by a peculiar device, which is illustrated in Fig. 2. It consists of an electromagnet *g*, which acts directly on the spindle $p_2$ of the valve $p_1$ and a contact device consisting of a chamber *r*, containing mercury and provided with contact points $r^1$, $r^2$. Chamber r is in communication with the hydrogen pipe *m* through a passage $r^3$, and is connected with the pressure chamber by means of a conduit $r^4$, the area of which is controlled by the cock $r^5$. As the pressure of the hydrogen rises in the discharge compartment *b*, the mercury in the chamber *r* is forced upwards until it comes in contact with the contacts $r^2$. The circuit connected with this terminal, however, is open, and the magnet *g* is not energized, until the mercury reaches the contact point $r_1$. The valve rod $p^2$ is then pulled up and the valve opened, whereupon the mercury begins to fall down again, the valve, however, not being closed until it reaches the contact point $r^2$. The time taken in the performance of a complete cycle of operations will depend upon the differences of level of the two terminals of the valve-controlling device, and on the velocity of rise and fall of the mercury, which latter can be regulated by adjusting the opening through which the mercury passes and the relative height of the contact points.

*Cathode for Electric Detinning Baths.* M. Larnoes and J. Dunn, Streator, Ill. Patent 737,423, August 25, 1903. Application filed November 25, 1902.

This invention relates to an improved form of cathode, which is made of a plate of sheet-iron or steel and riveted to a transverse suspension rod, in order that there should be no obstruction to the scraping tool when the tin deposited on the cathode is removed. The plate is also provided with a handhole, so that it can be handled with great facility.

*Connecting Hook for Electrotypers.* J. W. Cornelius and J. Niemer, Cincinnati, Ohio. Patent 737,353, August 25, 1903. Application filed July 5, 1902.

The inventor describes two forms of hooks used by electrotypers for suspending cathode or anode plates into the plating solution. The hooks serve at the same time as conductors of the current, and are so constructed that the plates can be entirely submerged in the electroplating solution. The upper part of the hook consists of copper, while the lower part, in which the plates are held, is composed of lead, or a combination of lead, tin and antimony. The mechanical construction is described at length.

*Process of Zincing Objects by Electrolysis.* S. Szirmay, Budapest, Austria-Hungary. Patent 736,565, August 18, 1903. Application filed November 12, 1900.

The inventor proposes to overcome all the disadvantages in the commercial deposition of zinc by electrolysis, which he discusses at considerable length, by adding to an electrolyte consisting of sulphate of zinc, a certain amount of dextrose and of the mixed sulphates of aluminium and magnesium. The electrolyte is made up by first dissolving 13 kg. of sulphate of zinc per 100 liters of warm water. A mixture of 1 kg. in definite proportions of sulphate of aluminium and sulphate of magnesium, and 3 kg. of dextrose are dissolved separately in boiling water, allowed to cool and mixed together, after which the resultant solution is added to the zinc sulphate solution. Pure rolled zinc is used as anode, and the electrodeposition is carried out at a temperature of about 18° C., with a current of about 100 amperes per square meter of cathode surface, and 4 to 4½ volts. The electrolyte is maintained at its original concentration by adding periodically fifteen cc. of the solution of dextrose and the mixed sulphates per square meter of cathode surface.

*Electrolytic Decomposition of Saline Solutions.* A. B. Larchar, Oldtown, Me. Patent 736,982, August 25, 1903. Application filed October 9, 1900.

The specification describes an apparatus for the electrolysis of sodium chloride solutions of the diaphragm type. The cathode of this apparatus is of peculiar construction, consisting of sections of a soft steel grating, which form the four side walls of the inner compartment and serve to support the diaphragm which is stretched upon their inner side, and also the cover of the cell, from which the anodes are suspended. The cathode grating consists of a series of bars or slats, oblong in cross-section and ¾ inch wide by 0.049 inch thick, disposed at right angles to the plane of the wall, of which they form a part. The slats are spaced uniformly apart, and passages or channels are thus formed, leading outward from the diaphragm. In this way there is formed a lamellar cathode, which acts to divide the liquid into a great number of films, which pass from the diaphragm outwards through the cathode into the tank, which surrounds the whole construction. The diaphragm consists preferably of three or four thicknesses of asbestos paper, and the anodes are a series of graphitized carbon slabs, each inclined from top to bottom towards the diaphragm wall adjacent to it. Arrangements for drawing off the caustic soda solution and maintaining the rate of percolation are described in detail. The inventor states that he worked with an apparatus containing fourteen hundred slats of the dimensions given above, twenty-two anodes, each 1¼ inches by 4 inches in cross-section, and 20 square feet of diaphragm composed of three plies of asbestos paper, each 1-32 inch thick. The height of the cell was about 30 inches, and the depth of the brine about 24 inches. Six hundred amperes were used at a voltage of 3.8. The best results were secured by maintaining the level of the liquid inside the cell about 1½ inches above the liquid outside of the cell.

*Method of Recovering Tin from Scraps of Tinned Iron.* B. A. Bergman, Nyfors, Sweden. Patent 736,924, August 25, 1903. Application filed January 15, 1902.

The inventor claims to overcome all difficulties in the recovery of tin from scraps by the use of a depolarizing compound in the vessel in which the tin is dissolved from the scrap. He arranges an iron tank filled with a solution of caustic, into which is suspended a basket containing the tin scraps and resting on insulating blocks. On the bottom of the vessel there is a layer of oxide of copper, which is to play the role of a depolarizer. The arrangement is supposed to act as a battery and to charge a storage battery, which is to serve the purpose of furnishing current for the subsequent deposition of the tin from the alkali stannate solution obtained in the cell.

*Reduction of Nitro and Azo Compounds.* M. Buchner, Mannheim, Germany, assignor to C. F. Boehringer and Soehne. Patent 736,204, August 11, 1903. Application filed September 24, 1900.

The inventor states that he has found that tin may be precipitated even from strong acid solutions of tin in hydrochloric acid, which remain after the reduction of nitro or azo compounds, if the reducing process is so conducted that the tin employed is converted into stannous chloride only. Under these conditions there is no loss in current efficiency, as is the case when stannic chloride is employed, and even high current densities can be used. The reduction of para-amido-azo-benzol chloride is described as follows: 2.334 kg. of amido-azo-benzol chloride are intimately mixed with 2.66 kg. of electrolytically precipitated powdered tin. Five kilograms of water are then added, and the whole is well mixed, whereupon 4.5 liters of fuming hydrochloric acid are gradually added. After the reduction due to this mixture has been completed, the reduction bath is maintained in a heated condition for several hours, and then allowed to cool and drain from the excess of tin. The reduction solution is then poured into the cathode space of an electrolytic cell provided with a diaphragm. Any indifferent metal may serve as cathode and anode. The current density is about

1800 amperes (evidently per square meter). Towards the end of electrolysis, when the concentration of the tin ions decreases considerably, it is advantageous to reduce this current density. Thus, 2.5 kg. of tin are recovered from 2.66 kg. originally employed. The mother liquor may then be saturated with HCl gas in the cold and the chloride of paraphenyldiamine thus precipitated. The cooling of the cathode compartment is effected by a cooling coil arranged therein.

*Reduction of Nitro Compounds.* M. Buchner, Mannheim, Germany, assignor to Boehringer and Soehne. Patent 736,205, August 11, 1903. Application filed September 24, 1900.

The invention relates to the reduction of nitro compounds in the presence of lead, mercury, chromium or iron ions. The reduction of nitrobenzene by the addition of lead chloride to the cathode electrolyte is carried out in an apparatus provided with a diaphragm. The anode electrolyte consists of a 10 per cent solution of sulphuric acid, any suitable indifferent metal being used as anode. The cathode compartment contains a cylindrical platinum electrode, and a mixture of 500 parts by weight of fuming HCl, 500 parts by weight of water, 125 parts by weight of nitrobenzene and 50 parts, by weight, of lead chloride. The nitrobenzene is kept in suspension by constantly stirring the liquid, and is replaced by a fresh supply when it is consumed. During electrolysis the mixture is preferably cooled. The current has a density of about 1900 amperes per square meter, and is maintained until regular liberation of H takes place and becomes visible. After electrolysis is completed, the lead will be found in the form of fine metallic sponge, and none will be found in the cathode electrolyte. Instead of the fifty parts of lead chloride, forty parts of finely divided metallic lead may be added to the cathode electrolyte, and the process carried out in substantially the same manner. The conditions and proportions are also the same as above when ferrous chloride is added to the cathode electrolyte, but in this case only ferrous chloride, no metallic iron, is regenerated.

*Reduction of Aromatic Nitro-Compounds.* Max Buchner, Mannheim, Germany, assignor to Boehringer and Soehne. Patent 736,206, August 11, 1903. Application filed December 14, 1901.

The inventor has discovered that nitro bodies dissolved or suspended in an alkaline bath containing a salt, oxide, or other compound of an alkali, may be reduced to the corresponding amines, if a cathode, preferably of copper, is employed, together with powdered copper. The reduction of nitrobenzene to aniline is described as follows: A concentrated solution of sodium chloride is introduced into the anode compartment of a diaphragm cell which contains a carbon anode. The cathode chamber is provided with cooling and stirring devices. The solution in the cathode compartment consists of 1440 parts by weight of a concentrated sodium chloride solution, 50 to 100 parts by weight of powdered copper, and 123 parts by weight of nitrobenzene. The cathode is of metallic copper and the reduction is carried out, preferably with a current density of about 1500 amperes per square meter, and at 80° to 100° C. The voltage will, under these conditions, amount to about 5 volts. The process is discontinued after the amount of current calculated for the complete reduction to aniline has passed through. Examples are also given for the reduction of nitrobenzene to aniline with a copper cathode in alcoholic solution, with a barium chloride bath, with a platinum cathode in the presence of powdered copper, with a tin cathode in the presence of powdered copper, with a copper cathode in the presence of cuprous chloride, and with a nickel cathode in the presence of copper sulphate. The reduction of orthonitrotoluene to orthotoluidene, of meta-nitraniline to meta-phenylene-diamine, and of alpha-nitronaphtalene to alpha-naphtylamine is also described.

*Apparatus for Electroplating Small Metallic Articles.* J. F. Shelton, Fort Worth, Texas. Patent 737,162, August 25, 1903. Application filed September 16, 1901.

The specification describes in detail a mechanical construction, the main part of which consists of a perforated wooden cylinder, mounted on a wooden shaft, around which is wound a conductor in communication at its ends, with the negative terminals of a source of electricity. The positive terminal is connected to a series of rods, from which the anodes are suspended. The wooden cylinder is filled with the small articles to be plated, which are thus constituted cathodes. The cylinder is rotated during the operation of plating by a belt running on its surface.

### Primary Batteries.

*Portable Electric Accumulator.* L. A. Lammerts, Rotterdam, Netherlands. Patent 734,896, July 28, 1903. Application filed June 20, 1902.

The invention relates to portable electric accumulators, which are carried by the user in the pocket or are fixed to bicycles, etc. The object of the invention is to secure the conductors between the electrodes and pole terminals as effectively as possible from oxidation. The inventor claims that straight wires from the electrodes, passing through a layer of non-conducting material on their way to the battery terminals, are liable to rapid destruction, as the joint with the enclosing material is not sufficiently tight to prevent moisture from the electrolyte or the moist gases and vapors from penetrating to them and attacking them. He claims that a good protection can be secured by constructing the connecting wires in the shape of cylindrically coiled helical springs, as this shape has proved to permit the insulating material cast above the cells to adhere to and tightly surround the wires on all points.

*Dry Battery.* E. M. Fishell and M. H. Moffett, Cleveland, Ohio. Patent 733,178, July 7, 1903. Application filed April 14, 1902

The object is to provide a dry battery composed of a plurality of cells which are compactly and immovably enclosed in a case impervious to moisture and especially constructed to permit rough handling. The cell is primarily intended for use on automobiles and launches. The cells themselves are of the well-known form of dry batteries, with an outer cup of zinc, serving at the same time as electrode, and as the containing vessel. There are four cells of this kind arranged in a case, preferably made of tin, with semi-circular ends and flat sides. Provisions are made to maintain the cells and the terminals of the battery in their proper position.

*Galvanic Battery.* E. L. Anderson, St. Louis. Patent 732,811, July 7, 1903. Application filed July 9, 1902.

The object is to construct a galvanic battery of the zinc carbon type, the carbon electrode of which is provided with a depolarizing material, which battery shall be simple of construction and so arranged that the depolarizer can be easily renewed. The inventor uses a round hollow carbon electrode, placed in the jar which contains the electrolyte. The hollow chamber in the interior of the electrode is intended to receive the charge of depolarizer. A cylindrical zinc electrode surrounds the carbon. A removable bottom of porcelain holds the depolarizer in place in the hollow carbon electrode, which latter is of such a shape that it serves at the same time as cover for the containing jar. The electrodes can be easily removed for cleaning purposes or for renewal of the depolarizer.

*Battery.* D. Drawbough, Eberlys Mill, Pa. Patent 733,049, July 21, 1903. Application filed April 12, 1902.

The battery belongs to the class of dry batteries of the zinc carbon type. The outer cylinder of zinc constitutes one of the electrodes. The other electrode is formed of a flat stick of carbon, arranged in the center of the zinc cylinder. This carbon is surrounded by a composition of coke, plumbago and a small quantity of plaster of paris, so as to form a paste. Around this composition is placed a cylinder of paper

or other porous material which forms a partition between the composition and the electrolyte proper. The latter consists of concentrated caustic soda, with a small amount of alkali to hold it in place. The cell is hermetically sealed in the usual manner. Cheapness of construction is one of the advantages claimed for this battery.

*Galvanic Battery.* D. L. Winters, Chicago. Patent 734,646, July 28, 1903. Application filed May 27, 1903.

The object is to provide a battery to be used for operating spark coils of explosive engines, and similar applications. It is constructed in such a manner that the number of individual cells can be increased or decreased easily, without interrupting the current. The object is attained by constructing the electrodes in a peculiar manner, and providing long-yielding terminals or contact fingers, which press against the electrodes. When the latter are removed the contact fingers press against each other, thus forming a metallic connection.

*Electric Battery.* Henry Csanyi, Felsoe-Dobsza, Austria-Hungary. Patent 734,826, July 28, 1903. Application filed March 4, 1903.

The invention relates to a battery of the zinc carbon type, with a porous partition separating the electrodes. The carbon electrode is immersed in nitric acid of 40° to 50° B., and the zinc in an alcoholic solution of 5° to 15° B. of pernitrate of mercury and potassium cyanide. The inventor gives as an example of a suitable composition for the alcoholic solution the following: 1000 grms of 25 per cent alcohol, 150 grams of 48 per cent nitric acid, 10 grams of oxide of mercury, and six grams of potassium cyanide solution of 60 per cent. The partition may be formed of a mixture of clay and pieces of carbon, which latter have been burned by heating the mixture.

*Galvanic Battery.* H. Halsey, New York. Patent 734,546, July 28, 1903. Application filed Dec. 10, 1901.

The specification describes another arrangement embodying the inventor's idea as shown in former patents, of rotating one or both electrodes of a galvanic cell. Means are described in detail, whereby the carbon electrode of a zinc carbon cell is rotated by means of a small electric motor, driven by the cell itself.

*Electric Battery.* H. Halsey, New York. Patent 734,547, July 28, 1903. Application filed April 18, 1902.

In this arrangement the idea of the inventor has been to obtain the advantages derived by the use of a movable element without moving the element itself. Means are therefore provided to rotate the receptacle containing the electrolyte.

*Electric Battery.* H. Halsey, New York. Patent 734,548. July 28, 1903. Application filed April 18, 1902.

The object to provide a battery with movable elements, in which all the parts are to be simple and readily fitted together, and where the interior of the battery is readily accessible. The carbon element is hung upon a spider and revolves. The construction is described in detail.

*Electric Battery.* H. Halsey, New York. Patent 734,549. July 28, 1903. Application filed April 18, 1902.

The arrangement of this battery is such that the movement of the electrolyte is effected by one or more propellers, the movable shaft being either brought in through the bottom or the cover of the cell. A small motor driven by the battery itself again furnishes the motive power.

*Electric Battery.* H. Halsey, New York. Patent 734,857. July 28, 1903. Application filed April 18, 1902.

In this battery a series of stirrers are arranged which brush the electrodes of the element. They are carried on a shaft on top of the battery, and receive an oscillating motion by means of a cam situated on the motor shaft, which cam strikes and operates the end of a lever connected to the stirrers.

*Electric Battery.* H. Halsey, New York. Patent 734,858, July 28, 1903. Application filed August 2, 1902.

In this construction the movable shaft enters through the bottom of the vessel containing the electrolyte, and carries the carbon element of the battery, which, however, is not in direct contact with the electrolyte proper, but is surrounded by the depolarizer.

### Storage Batteries.

*Reversible Galvanic Battery.* E. W. Jungner, Norrkoeping, Sweden. Patent 738,110. September 1, 1903. Application filed April 17, 1899. Divided and filed again June 23, 1902.

The cell described in the specification works with an alkaline electrolyte, which is not changed during charge and discharge, but merely serves as an oxygen carrier from one electrode to the other. The positive electrode is made up of a mixture of hydrated peroxide of manganese and graphite, moistened with water, and is introduced between two perforated nickel plates, which have been connected in a suitable manner, and then subjected to pressure. The negative electrode is made in a similar manner, but the active mass consists of a mixture of ferric hydrate and graphite. The ferric hydrate has been partly reduced to ferrous hydrate and metallic iron by cathode electrolysis in an alkaline solution. Perforated plates of copper are used as carriers in this case. The electrodes are placed alternately in the cell and separated by a porous or perforated insulating material. When the cell is discharged the following reactions take place: 1. $Fe + KOH + 2Mn(OH)_4 = Fe(OH)_2 + KOH + 2Mn(OH)_3$. 2. $Fe(OH)_2 + KOH + Mn(OH)_4 = Fe(OH)_3 + KOH + Mn(OH)_3$. The reaction 1, which takes place only when the charging has been carried so far as to produce metallic iron, gives a voltage of 0.8 volt, and reaction 2 a voltage of 0.6 volt.

*Secondary Battery.* G. E. Hatch, Quincy, Mass. Patent 736,390, August 18, 1903. Application filed July 14, 1899.

The positive electrode of this battery is made up of red lead in the form of a paste, which is introduced into the parallel grooves of two rigid porous support plates, made of kaolin or a similar acid-resisting material containing no iron. A thin lead plate in the middle serves as conductor, but does not perform any supporting function of the action mass, which latter is held altogether by the porous plates. The thin conducting plate may be perforated and the holes thus formed filled with acid intended to act as a reservoir when the battery discharge is unusually high. The negative plates are formed by filling the active material into a shallow perforated wooden mold and reducing it by a forming process to metallic lead. A conducting plate of thin lead has been introduced into the active material before the forming takes place. It is claimed that by the forming process the plate is brought into the condition of a firm, coherent plate of porous or spongy metallic lead, which is self-supporting. In assembling the cell, the grooves of the above porous plates are preferably placed in a vertical position, in order to provide a free passage upwards for the gases.

*Secondary Battery.* J. Middleby, Malden, Mass. Patent 736,420. August 18, 1903. Application filed November 22, 1899.

The invention is intended to provide a storage battery in which negative electrodes of zinc may be used with positive plates of lead. The electrolyte used by preference is composed of a solution of pure water, to which is added, in the order named, about one-twentieth of its volume of chemically pure sulphuric acid, sulphate of mercury slightly in excess of what will be dissolved by the hot mixture, and carbonate of ammonia in the proportion of from two to four ounces to each gallon of the mixed water and acid. Each zinc electrode is confined between two porous plates, the edges of which are raised on all sides, except the top side, so that they form a containing vessel when put face to face. The positive plates are formed of active lead material in the usual manner.

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We have received from the Westinghouse Electric & Manufacturing Co. their circulars, 1044 for direct-connected railway generators and 1048 for railway motors.

## INTERNATIONAL CONGRESS FOR APPLIED CHEMISTRY.

Report of the Proceedings of Section X.
(Electrochemistry and Physical Chemistry.)

By H. Danneel, Ph. D., and J. K. Clement.

(Continued from page 402.)

Meeting on June 4, Afternoon.

### The Composition of Electrometallurgic Products Containing Silicon.

A paper on this subject was presented by P. Lebeau, of Paris. By melting together copper silicide and cobalt, the author obtained a compound having the formula Si Co. In iron silicides which contain 10 to 20 per cent Si the definite compounds SiFe and $SiFe_2$ exist and the silicide Fe $Si_2$ has also been prepared. A series of other compounds were also obtained by melting together metals with copper silicide. The metals Ag, Sn, Zn, Al form alloys with the copper and the silicon is obtained in the form of small crystals distributed through the mass. Other metals, however, act upon copper silicide, in that they take away the silicon from the latter and form other silicides. By dissolving the copper in nitric acid, which does not act upon the silicides, these can be easily isolated. The following silicides have been obtained:

| | | | |
|---|---|---|---|
| $Fe_2$ Si | $Co_2$ Si | $Mn_2$ Si | $Cr_2$ Si |
| Fe Si | Co Si | Mn Si | $Cr_2$ Si |
| Fe $Si_2$ | Co $Si_2$ | Mn $Si_2$ | $Cr_2$ $Si_2$ |
| | | | Cr $Si_2$ |

Nickel silicide was also obtained, but its isolation is difficult, owing to the fact that it is attacked by nitric acid. A thorough study of the ferrosilicides led to the conclusion that in the technical product the silicon is always in the form of $Fe_2$ Si. There was no discussion.

### The Specific Action of Metals in Electrolytic Reduction and Oxidation.

In a paper on this subject A. Coehn gave a comprehensive summary of the reducing action of different metals, especially upon organic bodies; and he traced the various "reduction potentials" back to Caspari's theory of overvoltage (Ueberspannung). According to this, different cathode potentials are required for producing hydrogen at cathodes of different metals.

It was next shown that this was no peculiar property of hydrogen alone, but that oxygen behaves similarly. In the case of the latter a lively evolution of oxygen gas takes places on bright platinum at 1.67 volts, on copper oxide at 1.48 volts, on nickel at 1.35 volts, and at spongy nickel even at 1.28 volts. With this phenomenon of overvoltage it is possible to explain a long series of chemical phenomena, which, up to the present were inexplicable.

A new example is offered in the case of Marsh's test for arsenic. While the addition of platinum sets up a more violent evolution of hydrogen, yet the hydrogen is not evolved with a potential sufficiently high to form arsenuretted hydrogen. If only zinc is present then the potential is sufficient. Coehn then spoke of the work of various investigators upon the electrolytic reduction of organic bodies; also on the oxidation of chromium salts, and on the electrolytic oxidation of p. nitrotoluol to p. nitrobenzoic acid which was formerly impossible, but which can now be carried out by making use of the overvoltage of oxygen on a $PbO_2$ anode.

In addition to the phenomena due to overvoltage, others depend upon the catalytic action of the metal. As example was mentioned the decomposition of formic acid into hydrogen and carbon dioxide which takes place when in contact with iridium or rhodium, but not with platinum or palladium. Overvoltage cannot here be the cause, for hydrogen goes off at the platinum without overvoltage. As a good instance of the phenomenon of overvoltage which has not yet been described as such, the speaker instanced the behavior of metals in chromous chloride. Chromous chloride is such a powerful reducing agent that a strongly acid solution evolves hydrogen of itself; when platinized platinum is immersed in a weak solution then hydrogen is also evolved. Measurement of its reduction potential, i. e. of the maximum pressure with which hydrogen is set free cannot be made in this way, as hydrogen is already evolved on platinized platinum at atmosphere pressure. Electrodes on which hydrogen has an overvoltage are charged to a higher potential when introduced into the solution. In the same way the potential of a metal when immersed in a solution which evolves oxygen, e. g. $H_2O_2$, NaClO, etc., differs according to the overvoltage which oxygen has on the metal.

In the discussion Loeb said that in the name "overvoltage" we use to comprehend a great many phenomena which are essentially different from each other; for instance, the cases in which the electrodes are inert and those in which they have a certain solution tension are distinctly different. Foerster called attention to the fact that the potential at which oxygen is developed at platinum anodes, continually rises during electrolysis up to a maximum; this rise of potential determines the oxidizing power of the anodic oxygen; on account of this rise of potential electrolytic oxygen often causes complete oxidation; this is the more the case the lower the temperature, because with higher temperatures the rise of the potential is smaller. Coehn has not observed such a rise of potential at nickel anodes; he believes that in Foerster's case some higher oxide of platinum is formed which has a greater overvoltage than pure platinum. Tafel does not believe that this phenomenon can be explained by the formation of a higher oxide, because the same rise of potential observed by Foerster at platinum anodes also sometimes takes place on cathodes. He also pointed out that in speaking of catalytic action of metals it is important to distinguish whether the catalytic action of the metal influences directly the electrochemical oxidation or reduction, or whether it influences subsidiary processes of purely chemical nature; it is very difficult to decide this question experimentally. Bodlaender, Coehn, Woehler, LeBlanc, Buchner, von Euler, and Nernst also participated in the discussion.

### The Dissociation Pressure of Soda Solutions.

A paper on this subject, presented by Kuester, is not electrochemical, but shows that the pressure of carbon dioxide from solutions of alkaline carbonates decreases gradually when the solutions become poorer in $NaHCO_3$ and richer in NaOH.

### The Preparation of Barium.

A paper on this subject was presented by Guntz. The barium was prepared by careful heating of 3 per cent barium amalgam, which had been obtained by means of $BaCl_2$ solution with mercury. The barium is white; heated with NaCl, compounds of the form NaCl, BaCl, are obtained. These are formed always when melted $BaCl_2$ is electrolyzed.

Replying to a question of Bodlaender, Guntz gave the figures which show that the double iodide has the formula NaI, BaI, 32 per cent Ba, 60 per cent I and 7 per cent Na were found.

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Session on June 6.

### Application of a Formula of Gravitation to the Process of Diffusion.

A paper on this subject was presented by E. Solvay, of Brussels. As the formula has not been experimentally proved its derivation and details may be omitted. The substance of it is as follows. If we have two miscible liquids, a heavy one and a light one, arranged in layers above each other, the heavier one being below, then the heavier liquid diffuses upwards against the force of gravity. There is a certain relation between the counteracting forces of gravity and of diffusion from which one can calculate the force required to separate a mixture into its two components. What is applicable to the force of gravitation must also apply to centrifugal force, and it

must, therefore, be possible to effect a separation by centrifugal motion.

In the discussion Bredig remarked that this relation had been shown thermodynamically by Gibbs, Gouy, Chaperon and Duhem, and that Gay Lussac had erected long glass tubes containing solutions of NaCl in the Paris Astronomical Observatory, and had investigated whether there was any variation in concentration at the upper and lower ends of the tubes, and that he found no difference. Van't Hoff and Bredig had experimented with a mixture of HI and hydrogen in a centrifugal machine and obtained a slight separation. The effect is, however, very small, and there is no prospect of separating air by centrifugal motion at one operation; by repeating the operation a great many times this very important problem might eventually be solved. Van't Hoff remarked that Solvay's formula might, perhaps, be tested with a mixture of iodoform and benzene, the densities of which are very different.

### Note on the Kinetics of Reaction of Reduction Methods.

H. Goldschmidt, of Christiana, presented a paper on this subject. The electrolytic reduction of nitro-compounds to amido-compounds take place in two steps. First nitroso-compounds are formed and these are then further reduced to amido-compounds. Goldschmidt found that the reduction of m-nitrobenzol sulphonic acid by $SnCl_2 + HCl$ is similar to the above. The velocity of the reaction is proportional to the concentration of $ZnCl_2$, instead of being proportional to its third power, as it must be if the reduction to the amido-compound were direct:

$$R.NO_2 + 3SnCl_2 + 6HCl = RNH_2 + 2H_2O + 4SnCl_4.$$

In accordance with the equation

$$RNO_2 + SnCl_2 + 2HCl = RNO + H_2O + 3SnCl_4$$

the reaction must therefore give first a nitroso-compound. It is the velocity of this reaction which is measured. The further reduction by means of $SnCl_4$ to an amido-compound has a velocity too great to be measured, as has been shown in the reduction of nitroso dimethyl analin chlorhydrate, and of p-nitrophenol. Moreover, in accordance with the second equation the velocity of the reaction should either be proportional to the square of the concentration of HCl or independent of it. This is not the case. A possible explanation for this is that the stanno ions do not participate in the reaction, but that an acid $HSnCl_3$ is first formed which then enters the reaction. That the stanno ions, as such, play no part in the reaction, can be seen from the fact that by using $SnBr_2$ and HI instead of the corresponding Cl compounds, one finds a velocity equation of the same form, but a velocity constant about 7½ times as large as with chlorine. The observation that the reduction is so much more rapid with $SnBr_2$ than with $SnCl_2$ might be of value to the preparative organic chemistry.

In the discussion Sackur said that if $SnCl_2$ dissociates at all, it forms univalent cations only

$$SnCl_2 = SnCl' + Cl'$$

similar to the dissociation of $PbCl_2$; he asked whether the observation of Goldschmidt could not be explained in this way. Goldschmidt promised to consider this explanation. Van't Hoff suggested isolating the intermediate product, namely, the nitroso-compound, by shaking. Elbs pointed out that Goldschmidt's observation is a very welcome supplement to Haber's scheme (compare the following paper).

### The Importance of Electrochemistry for Preparative Organic Chemistry.

A paper on this subject was presented by K. Elbs. In organic chemistry the application of electrolysis to preparative purposes is far more limited than in inorganic chemistry; nevertheless, the electrochemical processes for the production of carbon compounds has already attained considerable importance. For the preparatory electrochemistry of organic substances three fields come into consideration: The electrolysis of organic acids, the electrochemical reduction, and the electrochemical oxidation. In the present stage of development the electrochemical reduction is far more important than the other two fields for various practical applications.

The electrolysis of organic acids will likely never lead to methods of far-reaching usefulness, and there are at present so many difficulties in the way of electrochemical oxidation that very few successes have been attained. Whether it will be possible to overcome these difficulties to some extent we are at present unable to say.

In the case of electrolysis of organic acids, the aromatic acids do not come into consideration, as their alkaline salts break up at the anode, under evolution of oxygen, and regenerate the acid. In the case of the acids of the fatty series, the discharged anions react with one another in three different ways. Every one of these is sometimes useful as a process of production; from sodium acetate about 90 per cent ethane can be obtained

$$2CH_3.COO = CH_3.CH_3 + 2CO_2;$$

from sodium proprianate 60 per cent ethylen:

$$2CH_3.CH_2.COO = CH_3.CH_2.COOH + CH_2.CH_2 + CO_2;$$

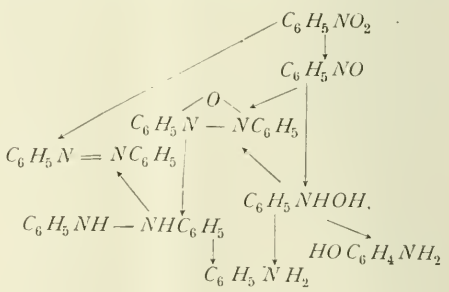
from sodium tri-chlor-acetate 40 per cent tri-chlor-methyl-ester of tri-chlor-acetic acid

$$2CCl_3COO = CCl_3.COO.CCl_3 + CO_2.$$

The preceding carboxyls do not take part in the electrolysis. On this fact is based the important electrosynthysis of symmetrical di-basic acids, for example, the formation of adipic acid in the form of its diethylester from potassium succinate:

$$\begin{array}{l} CH_2.COOC_2H_5 \\ | \\ CH_2.COOC_2H_5 \\ 2\,| \\ CH_2.COO \end{array} = \begin{array}{l} CH_2.COOC_2H_5 \\ | \\ CH_2 \\ | \\ CH_2 \\ | \\ CH_2.COOC_2H_5 \end{array} + 2CO_2$$

The *electrochemical reduction* makes use of the reducing action of the discharged cations, and is considerably successful in the reduction of aromatic mono-nitro and carboxyl compounds. The extensive field of the electrolytic reduction of aromatic mono-nitro compounds is best illustrated by Haber's well-known scheme, to which universal validity may be attributed, the perpendicular arrows denoting processes of reduction, the oblique ones other processes.




With vigorous reduction in moderately acid solution, the corresponding amine is obtained from the nitro-compound. The critical stage of the process is the hydrozyl amine. In a too strongly acid solution it changes over into amidophenol, and with too little acid or too feeble reduction into azoxybenzene. By using lead cathodes, or by adding tin or also copper compounds the nitro-group can be readily converted into the amido-group. This is an excellent method for the formation of amines.

The transformation of hydroxylamin into aminophenylen has only a very limited application as a method of preparation. By moderate reduction in alkaline solution hydroxylamin condenses rapidly and completely to the azoxy compounds; the

latter, being liable to further reduction to the hydrazo form, is generally difficult to obtain. The last-named substance is oxidized by the remaining nitro-compounds, and simultaneously by the oxygen of the air to the azo form. This makes it an easy matter to obtain an excellent output of azo compounds. The same remark applies to the hydrazo compounds, which in general cannot be readily further reduced, and therefore constitute the final product of reduction in alkaline solutions.

The electrochemical reduction of carboxyl groups is successful only on cathodes which have an overvoltage, especially on lead cathodes. Three stages of reduction are to be considered.

$$1.\quad 2\!>\!C=O+2H=\!>\!C\cdot OH$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\quad |$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\quad >C\cdot OH,$$
$$2.\quad >C=O+2H=>CH\cdot OH,$$
$$3.\quad >C=O+4H=>CH_2+H_2O.$$

In the reduction of ketones, reactions 1 and 2 usually take place, 1. the penacone synthesis more readily in acid, 2. the formation of alcohol more readily in alkaline solution:

1. $2CH_3.C_6H_4.CO.C_6H_5 + 2H = CH_3.C_6H_4.C(OH).C_6H_5$
$$\qquad\qquad\qquad\qquad\qquad\qquad\quad |$$
$$\qquad\qquad\qquad\qquad\qquad\qquad CH_3.C_6H_4.C(OH).C_6H_5$$
2. $C_6H_5.CO.C_6H_5 + 2H = C_6H_5.CH(OH).C_6H_5$

With acid amides and imides and derivatives of uric acid 3 is generally the principal reaction:

$$\begin{matrix}CH_2\cdot CO\\ |\\ CH_2\cdot CN\end{matrix}\!>\!NH+4H=H_2O+\begin{matrix}CH_2\cdot CH_2\\ |\\ CH_2\cdot CO\end{matrix}\!>\!NH.$$

*Electrochemical oxidations* by means of discharged anions are in no direction so well under our control, as the reduction by means of discharged cations. To begin with, the selection of a suitable solvent offers considerable difficulties. One can scarcely speak of general electrochemical methods of oxidation, but rather of special processes, such as the oxidation of ethyl alcohol to iodoform, and a few similar cases which allow of no generalization.

### The Importance of Electrochemistry for Technical Organic Chemistry.

M. Buchner, of Mannheim, presented a paper on this subject. While electrolysis has come to be of enormous importance in the production of inorganic compounds, many obstacles retard the introduction of electrochemical methods in the technology of organic chemistry. Most organic compounds are non-conductors of electricity, and the anodic and cathodic products of decomposition of the few organic compounds which are electrolytes have no industrial value. Furthermore, the products of electrolysis, instead of being the simple compounds which are desired, are usually complicated mixtures. It is quite natural that electrochemical methods are only adapted as auxiliary, though very important for the manufacture of organic compounds. The first instance of an electrolytic method attaining decisive importance is in the manufacture of indigo, a process now carried out on a large scale.

Owing to the high price of Weldon chlorine, and the great dilution of Deacon chlorine, chemically made chlorine is not suitable for this purpose, so that the Baden Anilin and Soda Fabrik has erected a 3000 to 4000 hp. plant for the electrolytic decomposition of sodium chloride. The Griesheim-Elektron process is used. It has the great additional advantage that simultaneously the alkali required in the indigo smelting is produced at the cathode.

A process of similar importance is the electrolytic oxidation of chromium sulphate to chromic acid by the well known process of the Hoechster Farbwerke for the manufacture of alizarin. The process is a so-called electrolytic regeneration process. Its essential technical advantage is that the same amount of oxidizing agent always remains in use and consequently the capacity for oxidation is almost unlimited. By means of an ingeniously constructed cycle the same sulphuric acid passes without loss continually through the steps of manufacture, furnishing the necessary oxygen.

Finally, may be mentioned the importance which inorganic electrolytic processes have for the so-called finer preparative organic chemistry, as, for example, the electrolytic production of metallic sodium, great quantities of sodium being now consumed in the manufacture of potassium cyanide; if sodium amide is adopted for the manufacture of indigo, the demand for electrolytic sodium will be greatly increased. The reduction of nitric acid in acid solution to hydroxyl amine is technically very important in the production of organic compounds.

While the direct electrolytic reactions are at present of no practical utility, the second class of electrolytic reactions—those which accompany the electrolysis of inorganic electrolytes, acids, salts and bases, by which the organic substances present in the electrolyte are oxidized, chloridized, iodized or reduced—are of great importance for technical chemistry. The ordinary chemical oxidation or reduction of an organic substance with an oxidizing or reducing agent, which is prepared in a separate process, consists of two steps: the manufacture of the oxidizing or reducing agent, and the oxidation or reduction itself. It is here of no account whether the same factory carries out both processes or not. In either case the expenses for material, apparatus, sinking fund and labor have to be paid. By carrying out the oxidation or reduction electrolytically, the two separate processes are merged in one common simplified process, thus reducing the costs of apparatus, material, labor and sinking fund. The one operation can, of course, not be carried out without an equivalent expenditure of energy for the production of the oxidizing or reducing agents. Notwithstanding the necessity of an extra mechanical plant, the combined process means a technical simplification. The electrolytic oxidation or reduction of organic compounds does away with intermediate operations, allows a simplified development and manufacture of much purer products, and finally surpasses the purely chemical process because by dividing the cell into compartments by means of diaphragms several chemical substances may be produced simultaneously, and a certain amount of electrical energy required for the electrolysis can be saved.

The technical application of the anodic processes to the electrolytic production of organic compounds has made up to the present time very little progress. There are as yet no methods of general importance. On the other hand, through the brilliant work of Elbs, Gatterman, Haber, Haeusermann and Loeb, the field of electrolytic reduction, especially of aromatic nitro-compounds, has been opened to the application on an extended scale. The principal products of the reduction of aromatic nitro-compounds which are of technical importance are the amido phenols, hydrazo compounds, and amines. The former can be made according to the patented process of Friedrich Bayer & Co., in Elberfeld, by the electrolytic reduction of nitro hydro-carbons of the benzene series in sulphuric acid solution.

When one considers that the use of zinc for the production of hydrogen is expensive, and that in this method the alkali which is required for the reduction is lost, the outlook for the electrolytic manufacture of hydrazo compounds appears very promising. For this reason it has been the object of numerous patents. Especially to be mentioned are those of the anilin factory of A. Wuelfling in Elberfeld, covering the well-known Elbs methods of reduction, and of the dye works of Friedrich Bayer & Co. in Elberfeld. The technical value of the latter process lies in an enlargement of a method of Elbs' for the electrolysis of nitro-benzene suspended in alkaline alcohol,

with lead and mercury cathodes. In the modification of this method cathodes of metals whose oxides are soluble in alkali, are used in an aqueous solution of alkaline metal salts, so that the cost of current is distributed between several products.

The lack of a practical method for the electrolytic manufacture of aromatic amines, which are used in great quantities in the manufacture of dyes, lead the author to develop the following processes patented by C. F. Boehringer & Soehne in Mannheim-Waldhof (German patents 116,942, 117,008, 121,835, 123,813, 127,815, 130,742 and 132,404). Tin is chemically capable of producing the reduction; in order to produce the reduction with small quantities of tin, Buchner introduced a small quantity of tin into the space at the cathode. The cathode is made of a chemically inactive material and is surrounded by the nitro-compound which is to be reduced. The tin dissolves in the presence of the nitro-compound, reducing it to the corresponding amine, and is deposited again on the cathode. Further developments of the process showed that iron, lead or copper may be substituted for tin, other conditions remaining unchanged. While in this scheme for the electrolytic reduction of nitro-compounds in alkaline alcohol solution, Haber had already foreseen the theoretical possibility of reducing nitro-benzene to anilin, yet practically this reduction could not be realized, because by the reduction in alkaline solution only a azoxy-azo and hydrazo-benzene were obtained. He has now found that a copper cathode, or any other cathode, with addition of powdered copper, has the excellent property of electrolytically reducing aromatic nitro-compounds, of whatever constitution, suspended in alkali to their corresponding amines. The process depends on the fact that the velocity of reduction by hydrogen in the presence of copper is so great that the processes of condensation, which, with other electrode material, lead to azoxy-azo and hydrazo compounds, fall entirely in the background.

It is thus possible to combine the electrolytic production of amines with an entirely different electrolytic process of the electrolytic decomposition of alkali chlorides, a process already operated on a large scale. The hydrogen evolved by the electrolysis of alkaline chlorides is generally a dead loss, there being no application for it. Moreover, the generation of hydrogen, on account of the cathodic polarization, requires the expenditure of a certain e. m. f. By adding to the electrolyte in the vicinity of the cathode a depolarizer in form of an aromatic nitro-compound, a two-fold advantage is gained; the hydrogen which would otherwise be wasted is used economically in reducing the nitro-compound, and the pressure which is required for the electrolysis is reduced, thus giving a much greater yield with the same expenditure of energy.

The following example will serve to illustrate how this method may turn hitherto useless waste to good commercial advantage: The German inorganic chemical industry produces yearly 50,000 tons of bleaching powder by the electrolysis of alkali chlorides; this corresponds to 500 tons electrolytic hydrogen which escape unused. The electrolytic combustion of this amount of hydrogen with the oxygen of aromatic nitro-compounds at a suitable cathode, would produce 17 billions of kilogramcalories; moreover, the saving due to depolarization would at the same time produce 9,000,000 kg. of anilin—about three-quarters of the annual consumption of the entire world, and incidentally make a saving of 11,000,000 kg. of iron at present required in the manufacture of anilin.

## PRODUCTION OF POTASH IN GERMANY AND THE KALI SYNDICATE.

A recent consular report contains the following translation of an article, recently published in the *Deutsche Industrie Zeitung*:

"The German potash-producing industry has attained considerable importance within a comparatively short time. Its fame has gone beyond national boundaries. Over $49,980,000 are invested in Germany in this industry, not counting the capital of the numerous boring or drilling companies which the Prussian financial department has invested in its potassium mines. The number of workmen employed in this industry in the Empire is about 30,000 and the value of the product nearly $13,804,000. The importance to which the industry has attained is due to the efforts of the German Kali Syndicate. The prices secured by this organization must be regarded by their most bitter opponents as of the greatest value to the national industries.

The German agricultural classes ought to look upon the acts of the Kali Syndicate as particularly advantageous to them, not only in the fight for better prices which resulted in the potash fertilizers being sold much cheaper at home than they are abroad, but especially because of the potash propaganda of the syndicate which resulted in extending the uses of potash as a fertilizer. The consumption of kainite, inclusive of Hartsalz and sylvanite, increased from 175,000 tons in 1890 to 825,000 tons in 1902. On each 247 acres of arable land 862 pounds of potash were used in 1902, while only 156.5 pounds were used in 1890. This enormous increase would have been unthinkable but for the well-planned and energetic efforts and activities of the syndicate. A single company would have found such efforts and results absolutely impossible. The regulation of prices by the Kali Syndicate is very much better from another standpoint. The fact that foreign countries have to pay higher prices makes it possible for the syndicate to sell its products to German agriculturists a great deal cheaper than would be possible could the syndicate not regulate price and production. This campaign of price, in which the great German agricultural population has considerable interest, can be successfully continued only so long as the foreign consumers of potash do not succeed in obtaining a foothold in the Empire's commercial markets and mines. The recent efforts made by Americans—supported, we regret to say, by some Germans—to exercise a controlling influence over the German potash works must be regarded from a national standpoint as objectionable. Should these efforts nearly or even partially succeed, the potash market must receive a great shock and the continuance of the syndicate be made questionable. With the syndicate stands or falls the question of profit in the mines and mills of the German potash companies. For the number of the works their enormous capacity to produce is such that an entrance or an introduction of foreign competition would result in throwing the potash market into convulsions; at the same time, the possibility of finding profitable markets after the suppression of the syndicate would be very small.

The industrial crash of a great number of potash factories would be the inevitable result of any such change. If those in the syndicate and those outside wish to avoid the loss of markets and reduction in prices, they must look to a renewal of the contract with the syndicate.

These works, which will one day want to enter the syndicate, and which are endangering the position of the syndicate at the present moment by their unreasonable demands—particularly dangerous because of the present movement among the Americans—should keep their eyes open at this critical moment. They can endanger not only the success of the syndicate, but its very existence. If the syndicate can be continued, the hope of further development of the potash industry can be depended upon; but no one must be deceived into believing that the large profits of the past can ever again be realized."

## BOOK REVIEWS.

Secondary Batteries, Their Theories, Construction and Use. By E. T. Wade, London: The Electrician Printing & Publishing Co. Price $4.00.

This book is certainly valuable on account of the description

of many types of storage battery cells, both of historical interest and of actual importance. For the reader not well acquainted with the matter, it would be more valuable, however, if instead of giving a mere description of the numerous types of construction a criticism of each were made pointing out its advantages and its faults. In the historical review of the alkaline cells all the older cells of the copper-zinc type are described, but it is remarkable that the more modern development of these cells is not discussed, with the one exception of the Edison cell. For example, Jungner is entirely ignored.

What is said about manufacturing processes and the use of secondary batteries is valuable too, though naturally such a book cannot contain information on up-to-date manufacturing methods kept secret by the manufacturers.

The theoretical part of the book, however, needs improvements. The author takes the standpoint of the classic investigations of Gladstone, Hibbert and Tribe, but he does not accept the doctrines of modern physical chemistry in their application to the lead cell. The ionic theory of the lead cell may indeed be interpreted in rather different ways, and may, therefore, be regarded as somewhat uncertain, but some of the applications of modern physical chemistry to the lead cell are quite independent of any particular hypothesis, and should be referred to in a book dealing explicitly with the theory. The theories of modern physical chemistry have proven here so useful that, as Dolezalek points out in the introduction to his well-known book, there is, perhaps, no other case in which these theories are applicable with such a degree of exactness, and in which their value manifests itself so much as in the explanation of the phenomena of the lead accumulator.

A consideration of the principles of thermodynamics would have been particularly valuable, as it would have shown at once the impossibility of the author's theory of the formation during discharge of a long series of lead compounds with gradually varying $SO_4$ content.

That the drop of voltage during discharge is due to internal resistance is an idea still frequently entertained by some other authorities besides Wade; but a series of careful measurements carried out and afterwards published by Dolezalek and Gahl have clearly proved that this is not so. Although the resistance certainly increases upon discharge it does not do so nearly enough to account for the sudden drop of voltage at the end; and the true explanation of the phenomenon is to be found in the fact that the acid contained in the pores of the plate becomes more and more diluted. The electromotive force, therefore, becomes lower and lower, just as if the acid of the whole cell were decreasing in the same degree. The drop of voltage is increasing in speed, as for very dilute acid the voltage is influenced by concentration changes much more than for solutions of higher gravity.

It may be hoped that a new edition will bring this book to a modern standpoint and make it a thoroughly reliable book on the subject of storage batteries.

## CURRENT NOTES.

Electrolytic Production of Bleaching Liquors.—The article by Dr. W. H. Walker, published in our September issue, contained two typographical errors. On page 441, left-hand column, middle of the page, the parenthesis should read: "When working a nine or ten per cent brine." The other correction is in the same column, last paragraph. The firm name "Siemens-Halske Co. of Berlin" should read "Siemens-Schuckert Co., of Berlin." This company manufactures the apparatus shown in figure 8, on page 442.

New Members of the American Electrochemical Society.—At the meeting of the Board of Directors, held at Niagara Falls on September 17, the following gentlemen were elected members of the society: William H. Davis, Bear, Idaho; Dr. Michael Lark, Lockport, N. Y.; James F. McElroy, Albany, N. Y.; William Valentine, Lansingburgh, N. Y.; Prof. Elihu Thomson, Swampscott, Mass.; Henry H. Seabrock, Washington, D. C.; E. E. Armstrong, Niagara Falls, N. Y.

The Iron and Steel Metallurgist.—Announcement is made that *The Metallographist* is to be published under the title, *The Iron and Steel Metallographist*, beginning with January 1, 1904. The enlarged magazine is to be devoted to the development of the iron and steel industry. Messrs. Sauveur and Whiting are the editors.

The Western Chemical Manufacturing Co., of Denver, Col., have issued a very neat little Chemists' Handbook, of convenient size to carry in the pocket. It contains much useful information, concerning impurities in c. p. acids and tests for same, rapid assay methods for metallurgists, assaying of blast furnace slags, standard solutions, weights and measures, specific gravities, etc. A table of atomic weights is added with brief information concerning the properties of the elements and rules for qualitative tests. The information given in the book appears to have been carefully collected, and the handy little book should be quite useful to chemists and metallurgists.

## CORRESPONDENCE.

### CYANIDE SILVER PLATING BATHS

To the Editor of Electrochemical Industry.

Sir—I have read with great interest an abstract of an article published on page 465 of the September number of your journal on the decomposition of cyanide silver plating baths. The statement therein that the cause of the loss of cyanide which makes the regeneration of such baths necessary after a time, had not been ascertained, is hardly borne out by the facts: the cause referred to is now known by many engaged in the electroplating art as a very simple equation, as will appear later on.

Is not the expression, "loss of cyanide," somewhat misleading? Technically, the term "cyanide" implies a combination, as cyanide of potassium, cyanide of silver, etc. The metallic bases unite with the cyanogen CN of hydrocyanic acid HCN to form the cyanides.

Now, it is well known in the anhydrous state, both cyanogen CN and its component HCN are not readily decomposed by either air or light, but their aqueous solutions gradually break up into a series of different substances, as oxalic, formic, ureamic acid and ammonia, and other combinations; in a plating bath, a portion of cyanogen CN, as hydrocyanic gas, also passes off in the free state from the moment such solutions are formed; heat and excessive light also greatly accelerate this evaporation and decomposition.

It is also true, as stated by Messrs. Jordis and Stramer, that the loss of cyanogen CN is much greater in a solution while under electrolysis than when idle. As known, when a solution of potassium cyanide is freshly made and bottled up, so as to be airtight, it will be found, when opened after a long time, to be as efficient as when freshly made, if not exposed to too strong a light.

My experience with potassium cyanide plating solutions many years ago does not agree, however, with the result obtained by authors referred to in the statement that the use of silver chloride in the bath results in less resistance to the current as compared with the pure cyanide bath. Just the reverse was the case, and for this reason, the formation and deposition of insoluble potash salts on the anodes during electrolysis, as the cyanogen disappears, not only greatly increases the resistance, but the solution is robbed of its metal just in proportion as the component of cyanogen is diminished, and renders the anodes incapable of replenishing the metal deposited on the cathode, because their coating of oxide and potash salts becomes more and more insoluble as the solution loses its cyanogen.

Hence, in preparing such a bath I always preferred to make up the solution with either the cyanide of the metal, or dissolve

the proper amount of metal in a solution of potassium cyanide by the battery process, so as to eliminate as far as possible the accumulation of an excess of potash or other salts in the solution. For this reason it is more economical to use the pure potassium cyanide rather than the cheaper commercial article. But with the best of such solutions, deterioration and decomposition soon set in, and it is necessary to replenish the wasted energy of the bath. Unfortunately, as the cyanogen CN decomposes and passes off it leaves the potash salts behind to clog and slime the anodes—for the solvent power of such solutions to remove the anodic oxidation products rests entirely with the CN, or HCN, and is in proportion to their amount present in the bath.

To minimize the accumulation of these salts, I had recourse to a plan which I found to be very satisfactory. Instead of adding fresh potassium cyanide from time to time, as is customary, I passed HCN gas into the solution by decomposing under the well-known formula yellow prussiate of potash with dilute sulphuric acid in a lead retort over a gas flame, passing the gas HCN through a wash bottle, thence by tube directly into the plating solution. The uncombined potassium carbonate readily dissolved the gas, and the bath was at once restored to its original condition, and any insoluble coating on the anodes, left from the last electrolysis, would be instantly dissolved. Thus, the active oxidation of the anode and solution of the metal was completely restored. This introduction of HCN was repeated as often as the cyanogen diminished.

It is customary with some platers to use an aqueous solution of commercial HCN in their plating baths instead of potassium cyanide as a regenerator, but it is a dangerous and expensive article to keep on hand, exceedingly poisonous, and soon decomposes unless carefully sealed up and kept from the light.

Regarding the use of silver chloride in plating baths, while I do not recommend it as compared with silver cyanide, yet excellent plating solutions are so made and used. I have repeatedly used it, but for reasons stated prefer either the silver cyanide or the battery process described. The statement of Jordis and Stramer that in a bath of silver chloride the loss of cyanide and increase of "carbonate" is greater than with the use of pure potassium cyanide, seems to me to involve an erroneous equation; also their further statement that the increased formation of "carbonate" must have been brought about by an increased anodic oxidation caused by chlorine ions is unintelligible. As there is put into the solution so many units of potassium cyanide, I fail to see how the loss of "cyanide" can result in increasing the "carbonate."

The function of potassium carbonate in the preparation of potassium cyanide is to absorb and dissolve the HCN. Now, when the latter disappears, it simply leaves behind an equivalent of uncombined potassium carbonate, but it simply could not increase the latter—nor do I comprehend how, when silver chloride is used, increased anodic oxidation could be caused by chlorine ions.

It would be more in accordance with the chemical action observed to state that the disappearance of cyanide, where silver chloride is used, would cause an equivalent of chlorate to combine with an equivalent of potassium carbonate to form a complex subsalt. The fact is that the disappearance, passing off or decomposition, call it what you may, of the CN from a plating solution, simply leaves an uncombined portion of the potassium carbonate or other salts in the bath, and a restoration of the CN or HCN is all that is required to restore the same to full working efficiency. The process I used, as described, gave the best results, as it ensured the non-loading of the bath with troublesome salts. To sum up, therefore, I can state that the cause of the loss of "cyanide" (cyanogen) in plating baths is well known in the art, namely, that it is owing to the unstable character of HCN, which, when passing off, leaves the solution inert.

Again, can a bath containing silver chloride be used? It certainly can, and is used every day with good results, but is not equal to the silver cyanide bath. The statement of Jordis and Stramer that more cyanide disappears than is equivalent to the amount of "carbonate" found, is contradicted by their first statement, that the loss of cyanide is accompanied by an increase of "carbonate." Perhaps the translation is at fault. Their statement, however, that freshly made baths are entirely satisfactory is quite correct. A plating bath begins to degenerate from the hour it is made, because of the unstableness of the chief solvent, the HCN.

CINCINNATI, OHIO. JAMES POWELL.

To the Editor of ELECTROCHEMICAL INDUSTRY.

Sir—The translation of the article referred to by Mr. Powell is correct. The authors do not, however, make the statement in the original, nor is it made in the translation, that the loss of cyanide is "accompanied" by an increase in carbonate; they simply say that "the loss of cyanide and the increase in carbonate is always greater with the working bath than with the idle one, etc.;" nothing is said about the ratio of such loss and increase. The contradiction referred to by Mr. Powell, therefore, does not exist. "Loss of cyanogen" necessarily involves a loss of cyanide.

COMPILER OF THE SYNOPSIS.

## AN ALLEGED SUBOXIDE OF SILICON.

To the Editor of ELECTROCHEMICAL INDUSTRY.

Sir—In the discussion following my paper at the recent meeting of the American Electrochemical Society, Mr. Cowles asked if I had ever found any evidence of the existence of a suboxide of silicon in carborundum furnaces. He stated that Prof. Mabery had analysed a certain amorphous substance, apparently resembling the so-called "white stuff," produced in the Cowles furnace in 1885, and had found that it was a "suboxide of silicon."

I do not know what methods Prof. Mabery employed in his examination of this substance, but a possible explanation of the results he obtained has occurred to me.

Colson and Schutzenberger described certain experiments with silicon, in which they produced a compound having the formula $Si_4C_4S$, which on oxidation yielded a body having the formula $Si_4C_4O_2$ (*Comptes Rendus* 92, p. 1508 and 94, p. 1526).

Acheson has described certain compounds containing silicon, carbon and oxygen in various proportions corresponding to formulæ, such as $Si_2C_2O$ and $Si_7C_7O$. These compounds seem to vary in their composition as regards the amount of oxygen present, although the carbon and silicon are in a definite ratio—one atom of carbon to one atom of silicon. One of the possible compounds would be $Si_4C_4O$. In the following table are given the theoretical compositions of SiO and $Si_4C_4O$, and, omitting a small amount of iron and aluminium present as impurities, the composition of a substance produced by Mr. Acheson in one of his furnaces:

| | SiO | $Si_4C_4O$ | Substance from Acheson furnace. |
|---|---|---|---|
| Silicon ..... | 63.96 | 63.96 | 63.4 |
| Carbon ..... | .... | 27.03 | 26.8 |
| Oxygen ..... | 36.04 | 9.01 | 9.8 |
| | 100.00 | 100.00 | 100.0 |

Comparing these figures it seems possible that it was some substance approaching the composition of $Si_4C_4O$ that was produced in the Cowles furnace, and that Prof. Mabery, failing to discover the carbon present in the specimen, concluded that it was a suboxide of silicon.

It must be remembered that at the time of Mr. Cowles' experiment the compound silicon carbide (SiC) was unknown, for the crystalline form was first described by Acheson in his United States Patent, February 28, 1893 (applied for May

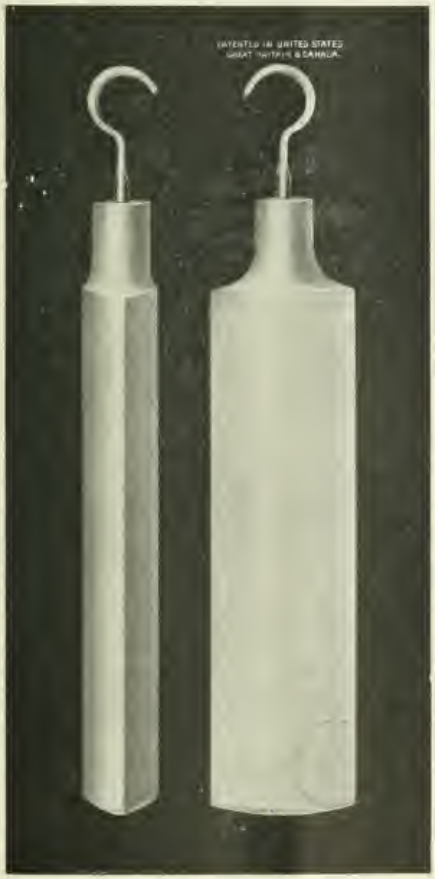
10, 1892), and the amorphous form by Schutzenberger in 1892 *Comptes Rendus*, t. CXIV., p. 1089. While it is true that the work of Colson and Schutzenberger, referred to above, dealing with the compounds of carbon, silicon and oxygen, was published as early as 1881-1882, this work does not appear to have been very well known.

FRANCIS A. J. FITZGERALD

NIAGARA FALLS, N. Y., September 21, 1903.

## ELLIPTIC ANODES FOR NICKEL, COPPER, ZINC, ETC., PLATING.

The adjoining illustration shows a form of anode for electroplaters which has just been placed upon the market by the Hanson & Van Winkle Co., of Newark, N. J. This company, which is one of the pioneers in the electroplating industry in this country, has realized the importance which the use of a suitable form and material of the anode has for a good deposit on the article to be plated. This fact has not been



ELLIPTIC ANODES FOR ELECTROPLATING.

thoroughly appreciated by electroplaters in the past, but recent investigations have shown that the proper form of the anode is of great practical importance.

In the June issue of this journal appeared an article by Prof C. F. Burgess and Mr. Carl Hambuechen, of the University of Wisconsin, in which they gave an account of a thorough test of anodes with elliptic cross-section compared with the ordinary flat anodes of rectangular cross-section. The authors pointed out that the important point is to get a large active anode surface, which does not mean merely the area of surface exposed to the electrolyte, but rather the area from which current passes readily into the electrolyte. They found that with an anodic cross-section the current density over the surface is much more uniform, so that the anode is uniformly corroded all around until it is reduced to a very thin rod or strip. The waste is thereby very considerably reduced.

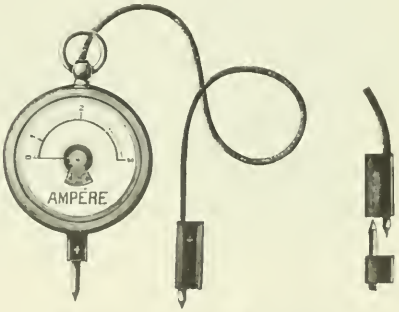
The Hanson & Van Winkle Co., who manufacture such anodes of elliptic cross-section in nickel, zinc, copper, etc., under patents in the United States, Great Britain and Canada, state that these results of the above scientific investigation are being fully confirmed by electroplaters in commercial practice. They have reprinted the article mentioned above with illustrations in their "Green Series" No. 2, which they will mail to anybody interested in the subject.

## POCKET VOLT AND AMMETER.

In view of the fact that small and comparatively inexpensive testing instruments are being imported into this country from France and Germany in large quantities for such purposes for which high-priced instruments are not required, the Talmont Electric Engineering Company, 150 Nassau Street, New York City, have designed a small pocket volt and ammeter with a very handy connector.

The instrument which is now being placed on the market is shown in the adjoining diagram. The one pin-connector is fixed to the instrument by a flexible cord, while the second one is loose, and may be easily and quickly screwed into the instrument when it is to be used, or may be pushed into the first one when one wants to carry the instrument in the pocket so that the points of both pins are well protected. The instrument permits easy and quick measurements in connection with a large number of accumulators or primary batteries.

The design of the instrument is based on a patented galvanometer system which is claimed to prevent the readings from being affected by magnetic fields or large masses of iron or by strong currents passing in the neighborhood. All



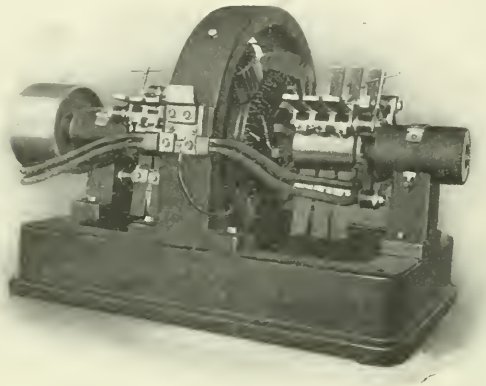

POCKET MEASURING INSTRUMENT

the conducting metal parts are carefully protected and insulated, which is a point of some importance, as lighting circuits and storage batteries have often earthed contact. The case is nickel-plated and the scale is drawn on white paper.

The instrument is said to be just as good as the best German and French instruments of this type; it is a perfectly new model and inexpensive and intended for such purposes in the shop or laboratory for which highly accurate testing instruments are too expensive or too inconvenient.

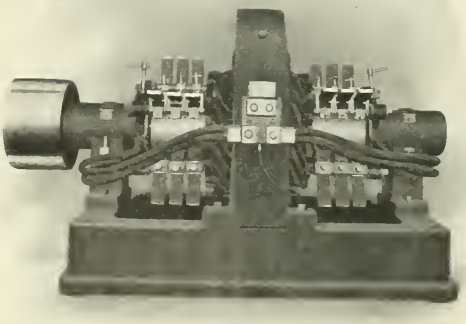
## DYNAMOS FOR ELECTROPLATING, ELECTROTYPING AND GENERAL ELECTROLYTIC WORK.

The adjoining illustrations show a new line of dynamos, specially designed for low voltage and powerful current work, and built by Mr. Charles J. Begue, 207 Centre Street, New York City. While we have already briefly referred to these machines in our August number, we are now able to describe



ELECTROPLATING DYNAMO.

them more in detail. In these machines all parts liable to need replacing are made strictly interchangeable, so that repairs may be made with a minimum of time and expense.



ELECTROPLATING DYNAMO.

By carefully selecting materials and embodying new features in the construction, the designer has succeeded in making the weight per unit of output very low. In the bipolar type the magnetic circuit is composed of a yoke of best grade soft steel accurately fitted and securely bolted to a soft gray iron base, which forms a secondary magnetic circuit in shunt with the yoke, thus reducing the reluctance and utilizing materials, ordinarily wasted. The poles and pole-shoes are in one piece and are made of the same superior grade of steel as the yokes.

The armature is built of carefully insulated punchings of soft decarbonized steel, thoroughly annealed. In the bipolar sizes the punchings are mounted directly on the shaft and keyed securely to the same. The multipolar sizes have the punchings held by spiders and secured by bolts. All sizes have the modern slotted or toothed armatures.

The shaft is of high carbon, crucible machinery steel and is accurately turned. The bearings are of hard phosphor bronze in one piece, and are of ample size to secure cool running, and are continuously and automatically flooded with oil while running. The oil wells are large and open at the top for inspection; they carry enough oil to last one to four weeks with one filling.

The commutators and brushes are of very large size, and are stated to be greater per unit of output than on any machine on the market. The brushes are of fine mesh wire gauze or of soft, thin sheet copper. The commutators are of tempered Lake Superior copper, well insulated with mica. The sleeve is secured to the shaft with a key.

The brush holders are simple; have a good clamp and adjustment and do not stick or bind on the brush stud. The current is carried from the brush to the stud by a heavy flexible conductor, so that the contact between the holder proper and the stud is not depended upon to carry the current.

The speeds of all machines of this line are moderate, and, as the armatures are light and well balanced, the bearings are prevented from getting hot.

For ordinary nickel, cyanide copper or brass plating, as well as electrotyping with two tanks in series, and for cases in which no very exact regulation of voltage is required or where no specially low voltage is needed, the plain shunt-wound type is used. These standard shunt machines are speeded in the smaller sizes ($P_1$ to $P_4$) to give 5 volts at no load, and the large sizes to give 6 volts. When running under full load the voltage drops in the smallest machines about 20 per cent, and in the largest sizes about $12\frac{1}{2}$ per cent.

There are, however, two common cases in which the shunt machine is not the best type. One is where nearly absolute voltage is required, as, for instance, for nickel-plating on zinc for certain classes of work. The other case is when an extra low voltage is required, say from 1 to 3 volts, as in silver-plating or when very thick deposits of copper are made in a sulphate solution. In both of these special cases, except with rather small machines, a separately excited dynamo is preferable to the shunt machine. The exciting current for the field magnets is here furnished from an outside source, such as the shop-lighting current or a small exciting dynamo. As the field is maintained in this case entirely independent of the armature current, very fine regulation is possible by means of a suitable field rheostat, even at the lowest voltages in commercial use.

In the following table of standard machines the weights of metal deposited are approximate, but necessarily not exact, as they are subject to variation under different conditions.

| | Speed. | Amperes. | Lbs. Nickel in 10 Hours. | Lbs. Copper in 10 Hours. | Oz. Troy Silver in 10 Hours. | Dwt. Troy Gold in 10 Hours. |
|---|---|---|---|---|---|---|
| P1 | 1,600 | 100 | 2.4 | 2.6 | 130 | 1,500 |
| P2 | 1,500 | 160 | 3.8 | 4.2 | 208 | 2,400 |
| P3 | 1,400 | 256 | 6.1 | 6.6 | 330 | 3,800 |
| P4 | 1,300 | 410 | 9.8 | 10.7 | 530 | 6,100 |
| P5 | 1,100 | 656 | 15.5 | 17. | 850 | |
| P6 | 970 | 1,000 | 24. | 26. | 1,300 | |
| P7 | 780 | 1,600 | 38. | 42. | | |
| P8 | 700 | 2,400 | 57. | 62. | | |
| P9 | 550 | 3,600 | 86. | 94. | | |

## THE EDISON NICKEL-IRON STORAGE BATTERY

The Edison nickel-iron alkaline storage battery which has recently been placed upon the market, has been tested by a number of authorities in the storage battery field. From a report made by Mr. W. Hibbert on tests in England the following details are gathered. The Standard Edison automobile cell is of rectangular shape, 13 inches high, has a cross-section of 5.1 x 3.5 inches, and weighs 17.8 pounds. It contains 14 positive and 14 negative plates. Each plate is made of sheet steel, nickel-plated, punched with 18 rectangular holes. In each of these holes is inserted a flat pouch or pocket containing the active material. The walls of these pockets are perforated by exceedingly fine, short slots to allow easy diffusion of the electrolyte.

Both positive and negative plates are alike, except in respect of the active material. The pockets in the negative plate contain finely divided iron; those in the positive contain "peroxide of nickel." The liquid is a 20 per cent solution of potash. A small quantity of electrolyte suffices as it acts merely as an electrolytic channel for "lifting" the oxygen from one electrode to the other.

The proximity of the plates does not apparently involve danger of short-circuiting. The plates are thin, but being made of steel their rigidity is exceptionally good. Mechanical stability is further assured by vulcanized rubber separators, the whole forming a compact mass, calculated to resist all the ordinary mechanical shocks it is likely to undergo.

The only special mechanical difficulty which seemed probable was the chance that the gases evolved during charging might eject some of the active material from the pockets. During the test, therefore, the pockets were watched carefully, especially during very heavy charges, but without any evidence of loss.

The cell is sealed in its steel case. Two stout connecting pins (from the two sets of electrodes) come through liquid-tight bushings of vulcanized rubber. These pins are made slightly conical, as are also the connectors which fit on them, and the mechanical finish and easy grip of the terminals add to the ease of using the battery. On the top of the case there are also a spring stopper with rubber flange, covering the hole by which the electrolyte is introduced, or distilled water added from time to time (to make up for the loss of water during charging); and a vent hole guarded by a gravity valve. This latter provides for the escape of the gas evolved during charge. The hole and valve are covered by a gauze nipple, which prevents escape of spray while allowing gas to pass. Acting on the principle of Sir Humphrey Davy's safety lamp, the same gauze further prevents any chance of explosion should a flame be brought near to the exit.

The e. m. f. is 1.33 volts. The internal resistance is 0.0013 ohm. The output at a discharge rate of 60 amp. is 210 watt-hours, or 11.8 watt-hours per pound of total weight of cell. The cell recovers its normal voltage almost instantaneously when the current returns to an ordinary value.

In the accompanying curves, Fig 1 shows the variation of the voltage during discharge at various discharge rates. Each curve corresponds to a discharge at constant current, the discharge rates varying from 30 to 200 amperes. This last is a high rate for a cell of this size, but the test showed that the cell could stand it without injury. It took the succeeding charge in an excellent way, and yielded the 30-ampere curve immediately afterwards. At 120 amperes the output was 91 per cent of the maximum output. Even at 200 amperes, the ampere-hour output is 82 per cent of the maximum.

In Fig. 2 are given the results of one out of many experiments, made to test the flexibility of the cell. The standard cell was discharged, starting at 60 amperes. After 5 minutes the current was suddenly increased to 230 amperes; 25 minutes after start the current was reduced again to 60, and so on, as shown by the curve. The cell having yielded this great current for short intervals, recovered almost instantaneously. It does not appear to be injured in any way, and subsequent charging and discharging seemed to be quite normal. An important point in traction cells is the rate at which they can be charged. Experiments on this point demonstrated that the

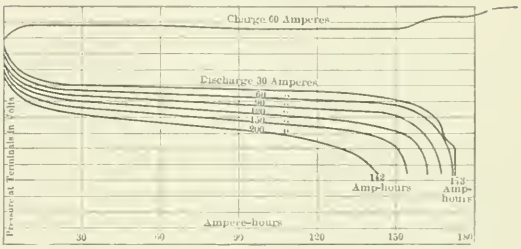



FIG. 1.—DISCHARGE OF IRON-NICKEL STORAGE BATTERY

Edison cell of the type under test may absorb 70 to 75 per cent of its full charge in one hour. A discharge after a one hour's charge showed that the cell could deliver 124 ampere hours out of the 175 put into it at this high rate.

After three months' work with very many charges and discharges the capacity of the cells was the same as at the begin-

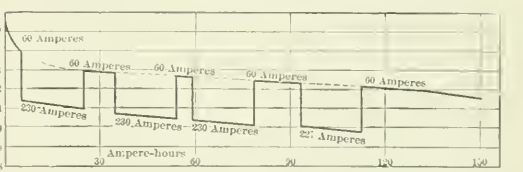



FIG. 2.—TEST OF FLEXIBILITY OF IRON NICKEL STORAGE BATTERY.

ning. It had neither increased nor diminished. Examination of the plates after three months' work did not indicate any signs of corrosion.

## A $25,000 PRIZE FOR THE TREATMENT OF GRAPES

The American Grape Acid Association is offering $25,000 for a process for making grape acid from grapes. They have issued a booklet setting forth their offer in detail, also a placard, of which the following is a copy: "The United States is a very large importer of grape acid, while California is a very large producer of grapes. The surplus of grapes means a quantity of raisins and wine demoralizing to the American market. The American Grape Acid Association has deposited securities with Daniel Meyer, Esq., banker, San Francisco, for the payment of $25,000 to any person who devises a process or formula for the utilization of California grapes containing over 20 per cent of saccharine, worth $10.00 per ton, to produce tartaric acid (perhaps by transforming the sugar in the grape into acid) at a price which would permit exportation without loss. The decision in awarding the amount to rest with three out of five of a jury who have been appointed to determine the matter, whose verdict would be final; the offer to close December 1, 1904. The following gentlemen constitute the jury: Percy T. Morgan, president of the California Wine Association, the largest distributors of wine in the United States; Andrea Sbarboro, president of the Manufacturers' and Producers' Association, of California; C. De Guigne, president of the American Cream Tartar Company; A. Schilling, of the firm of A. Schilling & Co. In case the formula is deemed by the inventor to deserve a larger payment than $25,000, and such process is patented or patentable in the various civilized countries, we ask for the privilege of making an offer for the sole right to use the formula. Co-operation is solicited. We shall

be pleased to mail these offers wherever directed, and publicity given to the enterprise will be appreciated. Address all communications to American Grape Acid Association, 318 Front Street, San Francisco."

## PERSONAL.

Messrs. F. A. J. Fitzgerald and P. McN. Bennie, who were formerly connected with the International Acheson Graphite Co., are now consulting engineers for special electrometallurgical work, with headquarters at Niagara Falls.

Mr. Woolsey McA. Johnson has been appointed metallurgist of one of the plants of the Lanyon Zinc Co. He is now located at Iola, Kan.

Mr. Truman H. Aldrich, of Birmingham, Ala., visited Salt Lake recently in order to study the methods of gold extraction.

## DIGEST OF U. S. PATENTS

Prior to July, 1902.

*Compiled by Byrnes & Townsend,*
*Patent Lawyers,*
*National Union Building, Washington, D. C.*

White Lead by Electrolytic Methods.—*Continued.*

589,801. September 7, 1897. Herman C. Woltereck, New York, N. Y.

Electrolyte consists of a mixture of an alkali metal bicarbonate and a salt of which the anion forms soluble lead compounds. The two salts are employed approximately in the proportions required by the reaction (one part bicarbonate to four parts of solvent). Lead, carbon dioxide and water are supplied as consumed. Prefers to employ salts of ammonium on account of low voltage required for their decomposition.

625,918. May 30, 1899. Ernest Bailey, Geo. R. Cox and Walter T. Hey, York, England.

Strikes arc to surface of molten lead to vaporize it. Injects through hollow carbon electrode a mixture of steam, carbon dioxide and acetic acid vapors, whereby white lead is formed and collected in bags.

627,002. June 13, 1899. Carl Luckow, Cologne-Deutz, Germany.

Electrolyte consists of mixture of alkali metal chlorate and carbonate in proportion of four to one. The solutions are very dilute (1½ per cent). Carbon dioxide and water continuously supplied.

631,839. August 29, 1899. H. C. Woltereck, New York, N. Y.

Product of United States patent 589,801, may be improved in covering power by (1) maintaining the temperature of the electrolyte below 25° C.; (2) removing white lead from the field of electrolysis as rapidly as formed; (3) continuously filtering the solution and injecting the carbon dioxide employed to regenerate it into the clear filtrate. Electrolyte is cooled by circulating water through cathode.

644,779. March 6, 1900. Joseph W. Richards and Charles W. Roepper, Bethlehem, Pa.

Lead anodes in electrolyte consisting of 5 per cent solution of sodium sulphite and acetate in proportions of 1 to 40. With current density of 100 to 200 amperes per square meter anode surface, the acetate is electrolyzed, yielding carbon dioxide, and lead carbonate is precipitated mixed with hydrate derived from action of sulphite. A small quantity of potassium nitrate may be added to facilitate solution of anode. Other organic acids, tartaric, formic, may replace acetic.

675,455. June 4, 1901. J. B. Tibbits, Hoosick, N. Y.

Modifies the process of patent 414,935, to produce colored white lead. To produce a blue pigment, attaches strips of copper to the face of the lead anodes, the product consisting chiefly of lead and copper carbonate. The depth of color depends on the relative area of the lead and copper. To produce a purple or violet pigment, coats the surface of both electrodes with iodine and adds anilin-red to the electrolyte. Employs a rubber or glass tube with lateral arms having downwardly-opening perforations to introduce the carbon dioxide.

675,459. June 4, 1901. John A. Yunck, Hoosick, N. Y.

Apparatus for executing the process of patent 414,935. Cell, an air-tight vessel having supports in its upper portion from which depend alternate foraminous anodes and cathodes of lead. A vertical shaft with radial arms having oppositely inclined vanes is journaled in the vessel, to agitate the electrolyte. Carbon dioxide is introduced through perforated pipes at the bottom.

675,460. June 4, 1901, John A. Yunck, Hoosick, N. Y.

Closed cell with rotary agitator. Lead anode with a supplemental carbon anode; lead cathode. Electrolyte, a 10° Baumé solution of sodium or ammonium nitrate, to each gallon of which is added one ounce of oxalic acid or sodium or potassium oxalate.

675,555. June 4, 1901, E. D. Chaplin, Winchester, and Henry G. Halloran, Boston, Mass.

Cell comprises a containing vessel with conical bottom and an inner porous cup. Anodes, lead pigs in the outer vessel around the porous cup. Cathode, a horizontal copper plate in the lower part of the porous cup. A hot solution of sodium or potassium nitrate or acetate fills both compartments, some sodium chloride being added to the anode compartment. The lead dissolves and is converted into chloride, which dissolves in the hot electrolyte and is gradually converted into oxychloride, which remains in solution. An alkali carbonate is added to the hot solution, precipitating the white lead. The caustic soda overflows from the cathode compartment and is carbonated, and the carbonate used for precipitating the white lead.

Dyes and Pigments.

256,330. April 11, 1882. Edward D. Kendall, Brooklyn, N. Y.

Produces aniline and toluine from the corresponding nitro-derivatives of coal-tar hydrocarbons. For example, places one part of nitro-benzine, or one part of a mixture of the same and nitro-toluine, in a porous cup with a mixture of water, thirty parts, and sulphuric or other acid or salt, two parts. The porous cup is placed in a solution of acidulated water, containing a carbon anode at each side of the cup. A carbon cathode, which may be covered with perforated cloth, extends to the bottom of the porous cup and is vertically reciprocated therein, thus effecting the reduction of the nitro body by hydrogen. May subsequently electrolytically oxidize the aniline or toluine or both, in a mixture of sulphuric acid and water, to a rose red, dark blue or green dye, by placing them in a porous cup with a carbon anode opposed to carbon cathodes outside.

294,051. February 26, 1884. J. K. Kessler, Milwaukee, Wis.

Cell, a vessel of wood having a transverse vertical partition at the middle, extending from the bottom part way to the top of the cell. Anode, blocks of copper at one side of the partition; cathode, a vertical sheet of copper at the other side of the partition. Electrolyte, a sodium chloride solution covering the partition. A cuprous chloride solution forms and settles to the bottom of the anode compartment and is drawn off and mixed with the caustic soda solution drawn from the cathode compartment to produce cuprous hydrate. The partition may be omitted, allowing the mixture to occur in the cell. The cuprous hydrate may be converted into suboxide by heating it to 100° C. or running boiling water through it. It may be converted into basic copper acetate by mixing it with neutral copper acetate, or into neutral copper acetate by mixing it with acetic acid.

(*To be continued.*)

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### THE BRADLEY PATENT DECISION.

On another page of this issue, we publish in abstract the decision rendered by the United States Circuit Court of Appeals in the case of the Electric Smelting & Aluminum Co., as complainant-appellant, versus the Pittsburg Reduction Co., as defendant-appellee. This decision is the outcome of a suit which is part of an extended litigation which has been going on for many years. In this litigation two patents have become famous; the Hall patent, relating to the use of alumina dissolved in a double fluoride bath as electrolyte, and the Bradley patent, referring to the internal heating of the bath by means of the electric current. There have been three different suits. One (in which the Pittsburg Reduction Co. was not involved) concerned merely the ownership of the Bradley patent; this suit was decided in 1897 in favor of the Electric Smelting and Aluminum Co. (successor to the Cowles Electric Smelting and Aluminium Co.). The other two suits were between the Pittsburg Reduction Co. and the Cowles Electric Smelting and Aluminium Co. concerning alleged infringements of the Bradley patent and the Hall patent respectively. By a decision of Judge Taft, rendered in 1893, in a suit of the Pittsburg Reduction Co. versus the Cowles Electric Smelting and Aluminium Co. the latter company was declared to be an infringer of the Hall patent. By a decision rendered by Judge Wing in April of this year, this case was reopened for the introduction of new testimony and reargument on its merits. This case is still pending. Besides this case there has been pending a suit of the Electric Smelting and Aluminum Co. versus the Pittsburg Reduction Co., wherein the former company has been suing the latter for infringement of the Bradley patent. This case has now been decided by the Court of Appeals in favor of the Electric Smelting and Aluminum Co. and the Bradley patent has been sustained. There is, of course, a remote possibility that this case may be taken up by the Supreme Court.

The manufacture of aluminium on a commercial scale, according to the present state of the art, involves both the use of alumina dissolved in a double fluoride bath as electrolyte, and the utilization of the heat produced by the current in the bath. The use of the electrolyte is covered by the Hall patent, which is owned by the Pittsburg Reduction Co. The use of the internal heating by means of the current is, according to the recent decision of the court, covered by the Bradley patent which is owned by the Electric Smelting and Aluminum Co. Should the legal situation remain unchanged, the commercial manufacture of aluminium depends upon these two patents, owned by the two different companies, and it will be impossible for anybody in the United States to make aluminium commercially, except under license from both the Pittsburg Reduction Co. and the Electric Smelting and Aluminum Co.

For one special reason the recent decision appears to be of great general importance. While the Hall patent will run out in 1906, the Bradley patent will run until 1909, so that the present method for making aluminium electrolytically will be covered by patents three years longer than had the Bradley patent not been sustained.

## ALUMINOTHERMICS.

We need offer no apology for publishing the elaborate and exhaustive article of Dr. Hans Goldschmidt on aluminothermics, although the subject is not strictly electrochemical. The principle common to all the different practical applications of aluminothermics lies in the facts that the oxidation heat of aluminium has a very high value, and that the combination of aluminium with oxygen proceeds with a very high velocity. These facts have been known for quite a while, but the development of the methods by which this thermochemical reaction was made a certain and controllable one, applicable to very different engineering purposes, is to be placed to the credit of Dr. Goldschmidt. The article published in this issue gives the most complete and up-to-date information published so far on this subject, and this information is authoritative, because it comes from the inventor himself.

The subject of aluminothermics is of special interest to electrochemists, because aluminium, as made commercially at present, is an electrochemical product. This is not incidental, but is to be considered as a special case of the general principle that by electrochemical methods we are enabled to produce that class of chemicals in which a great amount of energy is stored up. In fact, electrochemical methods are the most effective ones known at present for storing energy. We have to expend a certain amount of energy to make aluminium electrolytically, and of this we thus store in the aluminium an amount which it is able to give off later by combining with oxygen. The time and the place at which it is made to give off its energy is absolutely under control of the experimenter. The case of calcium carbide is quite analogous. In manufacturing calcium carbide in the electric furnace, we store in the calcium carbide a certain amount of energy which at any time and any place can be recovered by bringing the carbide in contact with water, thereby generating acetylene. Aluminothermics is thus connected with electrochemistry, since in the aluminothermic reaction, we get back energy which we have previously stored up in making the aluminium electrochemically.

It would, however, be wrong to suppose that the high oxidation heat of aluminium explains fully the effectiveness of the aluminothermic reaction for engineering purposes. Silicon has also a high oxidation heat, but, as Dr. Goldschmidt shows, it cannot be used as a substitute for aluminium in the thermic reaction. The reason is that, besides heat of oxidation, the speed with which such a reaction proceeds is another factor which determines its applicability to engineering purposes. These cases clearly indicate the limitations of the energy principle, which states nothing more nor less than that in all processes in nature the sum of all forms of energy in any distinct system of bodies remains unchanged as long as this system does not receive energy from, or give energy to, the outside. In the light of the energy principle alone, the conditions at the beginning and at the end of a reaction are equivalent, the energy being the same in both cases. If we want to know whether a reaction will go on in a certain direction or in the opposite direction, we cannot get an answer from the energy principle. True, we know that in chemistry Berthelot's rule, that the reaction goes on in such direction that heat is developed, is very often correct; but Berthelot's rule is not always true, and connot be considered of the same importance and scope as the energy principle. From a scientific point of view it is much safer to adhere strictly to the fact that the energy principle has nothing to do whatever with the direction in which a reaction goes on. To determine this, we have the second principle of thermodynamics which says that the reaction goes on in such a direction that the entropy increases. This principle, however, gives us the direction, but not the speed with which the reaction goes on; and the negative results of the attempt to substitute silicon for aluminium in Goldschmidt's thermic reaction indicate conclusively that the speed of reaction is a factor of the greatest importance. Concerning the speed of reaction we have not yet a general principle, and have to make in each case experiments to determine the speed for that case.

The article of Dr. Goldschmidt should be of special interest to those of our readers who are connnected with the iron and steel industries. A few years ago iron and steel men were in no way interested in electrochemistry. In the meanwhile numerous attempts have been made to apply electric furnace methods to this field, as is known to our readers from numerous articles on this subject published in this journal. But these electric furnace methods do not exhaust the connection of the iron and steel industries with electrochemistry, as is shown by the extended use to which the aluminothermic reaction may be put, not only for welding and repairing purposes, but also for improving steel castings. This illustrates the development which is steadily going on, and by which electrochemical methods are entering fields which were formerly believed to be absolutely outside of electrochemistry.

## CLASSIFICATION OF ELECTROCHEMISTRY.

In our present issue we publish the conclusion of Mr. C. P. Townsend's "Notes on the Classification of Electrochemistry." In reading this paper, one is astonished how large a field is really covered by this young art and science. Not long ago electrochemistry was considered a rather special branch of chemistry or of electrical engineering, and the number of those interested in this special field was rather small. But the situation has completely changed, as is indicated by the steadily growing interest among all classes of engineers and scientists in matters electrochemical. This is not surprising, in view of the fact that electrochemical methods are being tried or introduced in fields which had formerly been considered entirely outside of electrochemistry. Under these circumstances, a classification of all the various branches of electrochemistry is a timely subject for discussion.

Mr. Townsend's paper is neither a summary of the present condition of the several branches of electrochemical industry,

nor is it a resumé of progress. It purports to be merely an outline of a convenient and elastic classification of the subject matter of the art, with sufficient of comment upon the scope of the sub-divisions to indicate the character of the material included therein. The utility of the outline lies in its applicability to the classification or indexing of notes for reference. This is becoming daily a matter of greater perplexity and importance for everybody who wants to keep a convenient record of the progress of the art.

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Mr. Townsend's scheme of classification has recently been adopted unofficially by the Patent Office, and is now the working system by which the United States and foreign patents are classified in the examining division. It was primarily designed for this work, the essential condition of which is that the examiner shall have on hand for ready reference an index to notes which will guide him to the patent and other literature bearing upon the subject matter of any application which may be filed. In the case of patents these are, of course, themselves the notes and are filed under the indicated heads. The above condition is a very difficult one to fulfill in practice, but to a lesser extent it represents the need of every worker in the field.

## LOCAL SECTIONS OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

From a note on another page of this issue it will be seen that the establishment of local sections of the American Electrochemical Society at Madison, Wis., and at New York City is now well under way. The Electrochemical Society thus follows the example set by the American Institute of Electrical Engineers, which has found that this plan has had a beneficial effect in increasing membership. A similar result may be hoped for in the new departure of the Electrochemical Society, but in its case local branch organizations in the larger cities could fulfill a still more important mission. The most important broad result of the foundation of the national Electrochemical Society is probably the fact that it has firmly bound together in professional solidarity the numerous workers in the art and science of electrochemistry in this country. Much remains, however, still to be done in this direction, and it seems that in this respect local sections could accomplish very much. If meetings of the local sections are not loaded with elaborate papers, but are more devoted to a general and informal discussion of engineering questions which come up in the practice of every worker in the field, they would attract undoubtedly large audiences of electrochemists, chemists, metallurgists, electrical and mining engineers, and many would participate in the discussion and probably impart some valuable information, who would refrain from doing so in a more formal session. It is the rank and file of the Society which should be induced at meetings of the local sections to speak of their observations and of their troubles. Electrochemical methods are entering so many fields that it becomes difficult for any one to be fully conversant with the whole art. To counteract this disadvantage, there seems nothing better than local section meetings in which chemists, metallurgists and electrical engineers may exchange thoughts and information on subjects which concern all of them.

## ELECTROCHEMICAL NOTATION.

In this issue we publish the table of electrochemical notation proposed by Prof. Nernst, as chairman of a special committee of the German Bunsen Society and adopted by the Electrochemical Section of the Berlin International Congress for Applied Chemistry. That this table is not to be considered as definitive, is, however, indicated by the fact that a motion of Dr. Noyes, to appoint an international committee of five which shall make a report to the next Congress, was adopted in general meeting. The table of the Bunsen Society is, therefore, to be considered rather as a proposal, open for general discussion. It seems worth while to call attention to the fact that an international agreement on electrochemical units and notation should not be reached by a congress of chemists alone, but in co-operation with an international congress of electrical engineers. It would be very desirable if the St. Louis Electrical Congress of next year would take up the matter and state its position clearly, so that at the next Congress for Applied Chemistry, which will be held in Rome in 1906, the position which electrical engineers take toward the proposal will be clear. It is probable that some notations given in the German table will never find acceptance in this country, for instance, W for resistance. The expression "conductance in reciprocal ohms per centimeter cube" is incorrect and should read conductivity instead of conductance. A question which arises, is whether it is wise to include in a table of notation numerical data for constants of nature. Concerning notation a general agreement can be reached which shall then be adhered to. On the other hand, the figures for constants of nature are always more or less uncertain, and every new extended experimental investigation is liable to change them. For instance, in the table the charge of the univalent gram ion is given as 96,540 coulombs. This is the old well-known value which is in very extended use. From more recent investigations it seems, however, probable that 96,600 is nearer the truth than 96,540. In the same way the figures for all constants of nature are liable to be changed. Nevertheless uniformity in using these figures has great advantages, so that it might be considered preferable to give the numerical figures in the table of notation and to issue a new edition of the table whenever necessity arrives.

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While international congresses are undoubtedly the only proper places for issuing such tables, we like to emphasize that a thorough discussion of the matter in the columns of the technical and scientific press would be in order before a congress meets. In order to produce a table which will be generally adopted in practice, all the various workers in the field should have a right to make suggestions. Such a table shall be used by the rank and file of the science and art, and they must be heard before the table is adopted. An international congress, however, is not the place for such a thorough discussion. It should adopt what has been found to be the best in a thorough previous discussion. As this matter is of great practical importance, we would like to open our correspondence columns to a discussion of this question. Formulas are like a method of stenography for expressing concisely scientific and technical thought, and a uniform notation would render the understanding of formulas easy and would avoid much confusion.

## THE BRADLEY PATENT DECISION.

The United States Circuit Court of Appeals has just handed down the decision in the suit between the Electric Smelting & Aluminum Co. as complainant-appellant versus the Pittsburg Reduction Co. as defendant-appellee. The case was argued before Judges Wallace, Lacombe and Coxe, the appeal being from a decree of the Circuit Court for the Western District of New York, dismissing bill filed by the complainant for the infringement of two letters patent granted to C. S. Bradley, the patent in controversy on this appeal being No. 468,148, dated February 2, 1892.

After giving the subject matter of the Bradley internal heating patent and quoting some of its claims, the decision continues:

"The Circuit Court found that the claims were not infringed and dismissed the bill. The complainant assigns error, contending that the court erred in placing a narrow construction upon the claims and in holding that the defendant's process did not infringe. The complainant also contends that the court erred in holding that the success of defendant's process was due to the invention of Hall and not to Bradley * * *

"The defendant is engaged in producing aluminium. The investigation may, therefore, be confined to this one metal, for if the patent, when so limited, be valid and if the claims cover the defendant's process it matters not what else they cover or fail to cover. We start, then, with the undisputed fact that prior to Bradley's invention no one had ever succeeded in separating aluminium from its compounds solely by the use of electricity, or, in other words, no one had dispensed with external heat."

As to the reference principally relied on to anticipate or limit the claims of the Bradley patent, the court refers to the well-known experiment of Sir Humphrey Davy made in 1807, and concludes that "the fact that Davy's experiments were permitted to lie dormant during seventy-six years of intense activity in chemistry, electricity and metallurgy, is almost conclusive evidence that the complainant has overestimated its importance." Some other references are then briefly discussed and the decision continues, as follows:

"The principal expert for the defendant, Dr. Chandler, whose reputation for learning and ability is well known to the courts, although of the opinion that slight modifications of the previous methods would produce the Bradley process, nevertheless admits frankly 'I do not recall any one process which, when applied to the ore aluminium, would without any modification whatever have produced aluminium, in which process both the fusion and the electrolysis would have been accomplished by the electric current.' Not only did the electricians of the earlier art fail to produce aluminium by electricity alone, but the wrecks which strew the pathway which Davy pointed out nearly a century ago, offer mute but impressive proof of the genius of the man who first surmounted its many obstacles and reached the destination in safety. * * * The effort of inventors was directed to the perfection of processes in which external heat was employed to melt the ore and keep it in a fused state. The record abounds in such instances. * * * Many of these inventions were long after the introduction of dynamos and they continued to be made and practiced for several years after the Bradley invention. Indeed, so strongly was the inventive trend toward the employment of external heat that even the defendant's inventor, Hall, could not be induced to dispense with its use until 1880. When the defendant's works were started at Pittsburg, in December, 1888, the pots were built to be externally heated, and they were so heated for some time thereafter. * * * *

"Since the Bradley invention aluminium, which formerly was regarded as one of the precious metals, has become as common as copper and brass and its price has been reduced from $15 per pound to 25 cents per pound. We do not intend to intimate that this marvelous change was due solely to Bradley's invention, but simply, at this time, to emphasize the fact that it took place after Bradley's invention. If he has done nothing to produce this result he is, of course, entitled to no consideration whatever, but if he has contributed something, he is entitled to protection to the extent of that contribution, be it much or little.

"We have proceeded thus far to the conclusion that we are dealing with a patent which discloses a meritorious process for producing aluminium in large quantities, the essential features of which are, first dispensing with external heat, and, second, the use of the same electric current to produce and maintain fusion and electrolize the ores of aluminium. We are unable to discover anything in the prior art describing this process or anything closely approximating thereto. The patent is, therefore, not anticipated and its claims are entitled to a liberal construction.

"The judge of the Circuit Court, after careful and painstaking research, reached the conclusion that Bradley had made a valuable invention, but he failed to grant relief to the complainant upon the theory that the process which the defendant uses was an entirely separate invention, neither dependent upon nor subsidiary to the invention of Bradley. In this we think there was error. Hall's achievement should be considered in the light of an improvement upon Bradley's fundamental discovery.

"There can be little doubt that the defendant's process is a valuable one, and that to it is largely due the cheap aluminium of the present day. There is not the least disposition to detract from the merits of Hall or minimize his contribution to the art. Indeed, it may be conceded that, if the novel features so introduced be secured by a valid patent, he can hold the monopoly against all, Bradley included. This concession does not permit him, however, to appropriate the broad invention. He does not acquire the right to use the Bradley process simply because he has improved that process. He is entitled to enjoy what is his, but in doing so he cannot appropriate the property of another. The record discloses nothing unusual in this regard. It is rarely that an invention develops ultimate perfection in the hands of the inventor. The test of actual use discovers defects to be remedied and suggests improvements to be made. If the inventor produces a new and useful result he does not lose his reward, because he, or someone else, subsequently renders it more useful."

The court compares the process as operated by the Pittsburg Reduction Co., with the process described in the Bradley patent, and says: "That differences exist cannot be denied; that they are material is strenuously denied. * * * Speaking generally, it is thought that most of the points of variance relied on can be traced directly to the improvement introduced by Hall, namely, the use of cryolite as a solvent for alumina. Were it not for this change it is hardly probable that infringement would be denied. But the change of materials does not create a new process, but a new way of working the old process.

"The complainant's position regarding the Hall process, as used by the defendant, is sententiously stated in one of the briefs as follows: 'We contend that the process actually practiced by defendants is that of Hall *minus* the impracticable external heating feature shown by Hall, and *plus* the desirable and eminently successful internal heating feature of Bradley.'"

The conclusion of the decision reads as follows:

"Although the appeal included both patents the argument has been confined wholly to No. 468,148. It follows that the decree, in so far as it relates to letters patent No. 464,933, must be affirmed with the costs of this appeal, and in so far as it relates to No. 468,148 the decree is reversed with the costs of this appeal and the cause is remanded to the circuit court with instructions to enter a decree in favor of the complainant for an injunction and an accounting, with costs."

The opinion rendered was written by Judge Coxe and concurred in by Judges Wallace and Lacombe. We comment on it on another page.

## ON THE MANUFACTURE OF FERRO-ALLOYS IN GENERAL AND OF FERRO-TITANIUM IN PARTICULAR IN THE ELECTRIC FURNACE.

BY AUGUSTE J. ROSSI.

The manufacture of special steels has always attracted much interest, and in view of meeting the constantly increasing demand for a metal stronger than the ordinary carbon steel, or one possessing special properties better adapted to specific uses, metallurgists have studied the influence of metals, other than iron, which, introduced in the steel, might communicate to it the qualities required in each case.

What we say of steel may also well be applied to cast-iron itself. With the development of the railroads, of their equipment, cast-iron of a greater strength than the one that had been used before has become a necessity as material for wheels which have to stand now nearly double the maximum load permitted a few years ago. More attention has been given to mixtures, and even some manufacturers have thought of introducing in the cast-iron also, another metal which could increase its resistance. In this line of idea nickel has been resorted to, and now other metals or their ferroes are experimented with for car wheels and rails.

A metal can be introduced in iron in two forms, either as metal or as ferro, that is, an alloy of iron with one or more of the other metals. But, owing to the cost of the manufacture of the metal itself, which is generally more expensive than that of its ferro, this latter form has been most often resorted to.

To secure this increase of strength, however desirable it may be, the cost of the metal or ferro added must not be such as to become exclusive or limit its use to a few special applications. Unfortunately of the metals, other than iron, that can be used, many are of a comparatively rare occurrence in nature, met most generally associated with oxides of iron and often in too small quantities to be used in that state. It is thus that, while manganese ores are common enough, chrome and nickel ores are much less so, hence more expensive; and others, such as tungsten, molybdenum, vanadium, uranium ores are sparsely found, in small quantities and only in certain localities. This is not the case with titaniferous ores. There is hardly any iron ore in certain districts which does not contain a more or less important percentage of it, while in certain States of the Union, in the Adirondacks (N. Y.), for instance, in Canada, Sweden, Norway, Russia, and many other parts of the world, they are found in immense deposits, in mountain masses, associated with iron ores to the extent of from 5 to 40 or 50 per cent of titanic oxide and more. Titanic oxide itself, Rutile, is not only frequently found, but, in some newly discovered deposits in Virginia, it is claimed to have been met in a rock formation to such an extent as to render its use industrially and economically possible.

Titaniferous iron ores containing from 10 per cent to 50 per cent of titanic oxide can be as cheap and even cheaper than ordinary iron ores, so that, if the ferro-titanium, which can be manufactured from them, were to be conceded, after proper industrial and satisfactory tests to impart to iron valuable qualities, as valuable as those secured by other ferroes, it would prove also the most economical (excepting possibly ferro-manganese) for industrial applications.

The metals mentioned above occur in nature sometimes as sulphides (molybdenite, nickel pyrrothite), sometimes in combination with lime and manganese (scheelite and wolframite for tungsten), or in some other form, but most generally and abundantly also as oxides associated with oxides of iron, and very often a concentration is necessary to free them from the non-metallic gangue in which they occur. The concentrates are then the first materials for the production of the ferroes.

The reduction of some of these metallic oxides can be secured by carbon in the blast furnace (ferro-manganese, ferro silicon and ferro chrome even up to certain percentages), but, for others, the heat of the electric furnace is necessary and, even for the first named, the development of electrical engineering and the establishment of electrical power plants with favorable conditions of cost has rendered their electrical smelting more economical than the blast furnace method. This even has been the case for iron oxide itself, so that iron and steel, under favorable conditions of location, cost of ores and current, can be made in the electric furnace as cheap as in the blast furnace as it is claimed by some. We refer the readers to the several articles on this subject which have appeared in these columns on the electrical smelting of iron.

In all that follows we do not intend to treat of the reduction of the metals, other than iron, by electrolysis in the wet way or by igneous fusion, but of their electrical *smelting*, as the word is *commonly understood* and the reduction of their oxides as such or associated with oxides of iron, by methods which apply equally as well to all of them or their ferroes, let them be ferro-manganese, ferro-nickel, ferro-silicon, ferro-chrome, ferro-tungsten, ferro-molybdenum, ferro-vandium, ferro-uranium, ferro-titanium.

As regards ferro-silicon, we include it in the list, though silicon is not a metal. But though ferro-silicon up to 12 per cent silicon or thereabout can be manufactured in the blast furnace, yet above this figure the electrical treatment is the only economical and sure one. As to ferro-manganese, though manufactured currently in the blast furnace up to 80 to 82 per cent manganese, there are certain physical conditions of some of its ores which, in localities benefited by the facilities of obtaining both the ores and the current at very low rates, would render an electrical treatment advantageous.

As regards ferro-nickel and nickel, its manufacture by electrolysis or special metallurgical processes is too well known to be considered by us, but the methods of electric smelting to be described apply equally well to it, and may even, in certain special circumstances, prove preferable.

When these metallic oxides are reduced by carbon, the ferro metal contains an important amount of this element which may vary from 3 to 8 per cent or more, and though not objectionable for certain applications it is so for many others, for which an allowance of carbon less than 1 per cent is the only one admitted. Subsequent treatment of these high carbon ferroes with addition of lime or other substances in the electric furnace, may free them from a large part of their carbon but besides the cost of such method it is next to impossible, in most cases, to reduce the carbon to the admissible limit. Metals or ferroes quite free from foreign elements can be prepared by special chemical and other processes, but it must be borne in mind that in what follows we speak of metals *industrially* possible *on a large scale*. In order to obtain these ferroes practically free from carbon, another reducing agent has to be resorted to.

The property of aluminium to reduce metallic oxides has been known as a curiosity of laboratories for the last fifty years or so. By mixing together aluminium in powder with the oxide to be reduced in the same powdered state and placing the mixture in a crucible strongly heated in a furnace, the metal of the oxide was reduced to the metallic state by aluminium, which oxidized to alumina at the expense of the oxygen of the metallic oxide, owing to the great heat of formation of alumina. This reaction is *exothermic*, that is, once started at a point of the mass, it can proceed without the intervention of any external heat. Consequently, in this mode of operating the reaction was so violent as to project the whole mass from the crucible, becoming actually dangerous when experimenting on more than insignificant quantities of substances. It was due to Dr. Hans Goldschmidt to show how to control this reaction and to render it capable of industrial applications, not only in this line of reduction of oxides, but for producing, locally and at once an intense heat available for different purposes, such, for instance, as soldering in

1000 broken rails, or cracked steel castings, etc. In fact, this heat generating property of aluminium, as utilized by Dr. Goldschmidt, has formed the basis of a new branch of technology, the "aluminothermics," as it is called. We will only briefly record here such of its salient points as bear on our subject.

If a mixture of powdered aluminium and of powdered oxide charged cold in a proper vessel, is brought up, at one point of the mass, to the temperature necessary to produce the ignition of aluminium and start the reaction, the latter will proceed by contiguity of mass without the intervention of any external heat, until the reactions are completed. This starting is secured by a sort of fuse made of a mixture of aluminium and of an oxide readily yielding its oxygen (such as barium or sodium peroxide), both in powder or very fine grains, the finer the better. This fuse is primed in its turn by means of a ribbon of magnesium.

To illustrate the working of the method, let us apply it to the reduction of such a metallic oxide as ferric oxide $Fe_2O_3$. The equation $Al_2 + Fe_2O_3 = Al_2O_3 + Fe_2$ shows that 0.484 kg. of aluminium are required per kg. of metallic iron Fe.

1 kg. of aluminium by its oxidation to $Al_2O_3$ disengages 7140 calories. To reduce 1 kg. of iron, metallurgy teaches us that 1796 calories are required, and about 360 calories additional to melt the iron reduced from $Fe_2O_3$. If we add to this the heat necessary to melt the alumina slag resulting from the oxidation of 0.484 kg. Al (or $0.90Al_2O_3$), at the rate of 600 calories or thereabout per kg. of $Al_2O_3$ melted, we come to a total of heat necessary for the reduction of 1 kg. of iron (from $Fe_2O_3$), of some 2700 calories. As 0.484 kg. aluminium can supply: $0.484 \times 7140 = 3456$ calories, we see that we have a surplus of some 756 calories for losses, etc.

As applied to the manufacture of ferroes, this method requires necessarily a certain manipulation. The mixture of the two powders must be made very intimate and, owing to the rapidity of the reaction, two or three minutes at most, some of the oxide may escape reduction and a certain part of aluminium remain in the ferro or metal obtained. It is not our intention to criticise this method, but merely to point out possibilities when carried on a continuous and large industrial scale. At any rate, we may be allowed to say that it requires special care in the manipulations.

The method we have proposed and applied is based also on the use of aluminium as a reducing agent, but, instead of using this metal in fine powder or grains, we carry the operation in an electric furnace, in a *bath of aluminium*. The aluminium in waffles, ingots, scrap or the like, is first charged in an electric furnace and the current started. It melts in very few minutes, and in this molten bath we shovel the metallic oxide or oxides as such as concentrate. The reaction sets in at once, aluminium oxidizes with incandescence, the furnace becomes glowing white, and we can then reduce considerably or stop entirely the current until the reactions are complete or have lost of their intensity, when we supply again the current for a few minutes more to keep in a molten state the ferroes or metals obtained which can then be freed from any aluminium they may contain, if any, by the addition of a small quantity of the original oxide used. The metal is then cast. Other injurious elements in the ferro could even be removed by appropriate addition before casting.

As applied to ferro-titanium, for instance, the method consists in charging in the bath of aluminium titaniferous iron ores, that is, titanic oxide associated with iron oxide. Iron is reduced first, forming a bath in which the titanium reduced by the aluminium in its turn dissolves, yielding the ferro-titanium. Were rutile to be used (titanic oxide, practically free from iron oxide), instead of titaniferous iron ores, and were a ferro-titanium of a certain percentage to be desired, after or before the aluminium, there is charged in the furnace the proper quantity of good scrap-iron, thus diminishing the expense in aluminium by all the quantity of this metal which would have been required to reduce a quantity of iron oxide corresponding to the iron charged in the metallic state. The method is identically the same as applied to any other metallic oxides. Any compound, ferro or alloy of two or more metals with iron can thus be readily made, such as, for instance, chrome titanium iron, tungsten titanium iron, chrome nickel iron, etc. It is enough to charge in the bath of aluminium a mixture of the proper metallic oxides in a given proportion to each other. In case of nickel, the metal nickel can even take the place in the iron bath when rutile is used, and a nickel titanium alloy be obtained. If copper titanium were desired, the copper is charged with the aluminium in the furnace and when melted rutile is shovelled in the furnace.

We have treated by this method, amongst other oxides, tungsten concentrates containing $WoO_3$ 69.86 per cent, iron oxide 20.25 per cent, which could theoretically give an alloy containing 79.7 per cent tungsten. We obtained, in thirty minutes, with about 11-hp, 650 lbs. of a ferro-tungsten containing 76 per cent tungsten, that is, 97 per cent of what we calculated theoretically. The alloy could contain 0.60 per cent and 0.90 per cent of carbon and aluminium. None was found in the ferro. The weight of aluminium necessary for the reduction is obviously the same, let this metal be used in powder or in ingots, but the difference of prices of the two forms of aluminium is nearly as 2 to 1 in Europe, and over 2 to 1 here; prices of 70 cents per lb. having been quoted to us ( per ton) for the aluminium in powder, as against 30 cents for aluminium in ingots. Assuming the same cost of ores or concentrates, the same losses in the operation, the same incidental expenses and manipulations, the advantage must necessarily remain, as to cost of the product, on the side of the use of aluminium in ingots. For instance, referring to the reduction of iron oxide by aluminium merely as an example, and for illustration's sake, since we required 0.484 kg. Al per kg. of iron, or, which is the same, 0.484 lb. of Al per lb. of iron, on this score of aluminium alone the cost per lb. of iron reduced would be for the powder $0.3388, and for the ingot $0.1452, for the prices quoted above, and for any other ones in proportion.

Applying our aluminium method to ferro-titanium, we have made alloys practically free from carbon containing from 0.12 per cent to 0.75 per cent carbon and from 10 to 75 per cent titanium by the ton. Such alloys are very well adapted for the treatment of steel, but for seasoning cast-iron we have used ferroes containing carbon from 6 to 8 per cent and more and obtained with carbon as reducer, as in this case the presence of this element is of no consequence.

Before entering into some details of the tests we have made with ferro-titanium, we may say that the electric furnace that we used for the reduction of oxides by aluminium did not present any particular features. It was the same that we used when carbon was the reducing agent. In fact, any approved form of arc furnace would secure the same results. We have adopted, as the simplest, the well-known typical form of the old Siemens furnace of 1879.

Our current was alternating single phase current of 25 cycles. The primary current was 2200 volts and 75 to 80 amperes, which could be transformed into a secondary current of 20, 40, 60, 80, or 100 volts (to adapt it to the requirements of the different cases), and corresponding amperage by means of a transformer. Thus each furnace was supplied with a current of about 150 kw, or, say, 200 hp.

The furnace consists of a masonry of graphite agglomerated with tar (it may be round or square), incased in a box or sheathing of iron or cast-iron, connected at the bottom with one of the bus bars of the current. It forms the one electrode. A central cavity in the graphite masonry constitutes the crucible, in which can be moved vertically, up or down, a pencil of carbon or a bunch of such pencils forming the other electrode and connected by means of flexible cables with the other bus bar of the current. The furnace can be left open at top or closed, preferably by means of plates cooled by a circulation

of water; the motion of the carbon pencil can be obtained by hand, or by proper devices such as chains, pulleys and wrench or automatically by the current itself, as is the practice with calcium carbide furnaces. Masonry of refractory material may line vertically the sides of the crucible, acting as a non-conducting material and preventing the contamination of the alloy by carbon when aluminium is used as reducer; many other details of arrangement may be conceived and adopted in order to confine the heat as much as possible in the furnace and increase the output for a given current, but the operation is the same. When using aluminium as already mentioned, the metal is first charged, the carbon pencil having been lifted up for the purpose. The pencil is then lowered down, the arc started, and the oxides charged around the vertical electrode in the bath. When operating with carbon, the mixture of carbon in some form and of the oxides or concentrates is charged around the carbon pencil, the arc having been first started between the bottom of the furnace and the carbon pencil.

### FERRO-TITANIUM.

While the influence of metals introduced as such or more generally as ferroes, on the properties of iron and steel, has been ascertained sufficiently for some of them to make their use of common practice (for instance, manganese, nickel, silicon—considered as a metal, though not one—and more lately chromium), others, such as tungsten and molybdenum, have received more limited applications, and uranium and vanadium still more limited ones, owing to the rarer occurrence of their ores and the high price they command (especially the three latter metals). As to ferro-titanium, it was only known as a laboratory product, so to speak, some three or four years ago. Having given to the metallurgy of titanium and its alloy a special attention for several years and manufactured them on a large scale, we will enter into some details on their properties and uses.

We have made ferro-titanium, practically free from carbon, and containing from 4 per cent to 75 per cent titanium and more. What characterizes this ferro is the great infusibility, which is the greater as the percentage of titanium is higher. In this respect vanadium comes next and molybdenum immediately after. A 10 to 12 per cent ferro-titanium, with or without carbon, does not melt at the temperature of fusion of cast-iron and steel, but it dissolves in the molten metal in the same manner as platinum dissolves in steel. According to experiments of Faraday and Stodard, platinum and steel alloy in all proportions "and platinum will fuse, in contact with steel, at a temperature at which the steel is not affected."

Titanic oxide is not reduced by carbon at the temperature of the blast furnace or of a steel furnace, and all efforts to introduce titanium in iron or steel in this way have failed.[2] It is only by making a ferro-titanium and using it as a seasoner that it can be done, and it is only in the electric furnace that a heat sufficiently high for the reaction can be secured for the purpose. Titanium has a specific gravity of only 4.87 (Moissan) and, as a consequence, alloys containing a large percentage of titanium, especially if they contain also a large amount of carbon, have a low specific gravity. We have found 5.60 as the sp. gr. of a ferro titanium containing some 35 per cent of titanium and about 8 per cent of carbon.

Owing to this low fusibility and this lightness, we have found it advisable not to use for steel alloys higher than 20 to 25 per cent titanium, and for cast-iron not over 10 to 12 per cent, and in that we are entirely corroborated by the German practice, limited as it is to alloys made by the Goldschmidt method.[3] Furthermore, the use of higher alloys does not seem to be justified; the action of titanium on iron appears to be peculiar, very small quantities of the ferro securing unexpected results. Even such a small percentage as 0.10 of 1 per cent titanium found in the finished product has secured the desired improvement, as our own experience has shown us, and this has been confirmed by these German tests and others.[4]

It has been thought that apart from such specific and still more marked influence that titanium may have, if present in steel or cast-iron in much more important quantities, its action is one of purification of the metal, by removing the occluded gases, such as oxygen and nitrogen. The oxygen is removed owing to the great heat of formation of $TiO_2$ (titanic oxide), which is probably of from ½ to 2/3 that of aluminium, from *tentative* experiments made by us, and the nitrogen is removed by the well-known affinity of titanium for this element in which titanium burns with incandescence at 800° C or thereabout, just like iron burns in oxygen. This could explain why the metal treated is more dense, more homogeneous, more free from small blow holes, and consequently much stronger.

An examination of the fracture of cast-iron and steel treated with titanium will convince any one on this respect, and a microscopic examination of the steel treated in Germany has revealed the presence of minutest crystals of cyanonitride of titanium.[5]

Owing to these causes or others, steel containing 0.10 per cent of titanium and high in carbon (hard steels), C = 0.90 to 1.227 per cent, have shown as "limit of elasticity" and "reduction of area" figures only met with nickel steel or "very mild" steels low in carbon. In other words, titanium increases the ductibility of high carbon steels, notwithstanding the tempering qualities, giving to the fracture of the metal a satin-like appearance.

Added to cast-iron, in the proportion of 1 to about 2 per cent of a 10 per cent titanium carbon ferro, that is, about 1 to 2 lbs. of alloy to 100 lbs. cast-iron, either in the crucible, the ladle or the cupola, it increases considerably both the tensile and transverse strength, some 30 per cent and more in certain cases. Our own tests with cast-iron have been very numerous and others have been made in car-wheel works by outside parties. The president of one of these large establishments, in a paper read before the Railway Club of Pittsburg, on November 28, 1902, says that "titanium gives greater density to the metal, surprisingly increases transverse strength and gives a harder chill and wearing qualities to the wheel—hardening the tread and strengthening all parts of the wheel, including the plates." In an official test made in a shipyard, an increase in strength "of about 20½ per cent over their ordinary castings" was reported as the result of tests made in crucibles. We could quote concerning the details many other examples showing similar improvements in the resistance of cast-iron thus treated with this alloy. The above is, however, sufficient, we believe, to justify us in the conclusion that ferro-titanium is a very promising ferro, and that, its beneficial influence on the properties of cast-iron and steel once definitely established beyond doubt, it would take a very prominent place amongst the ferroes used in the iron and steel industry.

It would prove the cheapest of all of them, let the reducer be carbon or aluminium, as the raw materials can be obtained at a price as low, if not lower than that which ordinary ores command, and are found in abundance almost everywhere.

Rutile itself (titanic oxide) has been discovered in extensive deposits in Virginia, and we are told that a 90 per cent to 95 per cent titanic acid concentrate can be readily prepared at a very favorable figure, much lower than is possible with the concentrates of the rarer metals; specially so were there a sufficient demand for rutile to justify it.

The use of rutile, however, is only justified as more economical than that of titaniferous iron ores whenever ferro-titanium is obtained free from carbon by the aluminium meth

[1] Perry's Metallurgy, London, 1874, p. 178.
[2] Ibidem, p. 168. Howe's Metallurgy of Iron and Steel. First Edition, p. 88.
[3] Stahl and Eisen, June, 1901, Duesseldorf meeting, Volume XXI, No. 11.

[4] Ibidem.
[5] Stahl and Eisen, the article quoted above.

od, since the absence of material quantities of oxide of iron in the rutile reduces the amount of aluminium to be used in making the ferro or the alloy by all the quantity required to reduce the oxides of iron present in the ores. But this is true only if the price of rutile is not prohibitive.

Otherwise the titaniferous ores are preferably adopted as raw material, and as we have seen that the lower alloys are likely to be better adapted for industrial applications, they would prove sufficient. In this respect we will add that, should such be the case, should the price of rutile prove a serious item, and should alloys of the highest percentage of titanium be desired, we have used a method by which an "artificial rutile," so to speak, a concentrate of titanic oxide, can be cheaply secured. The ores we disposed of in our manufacture contained, some of them, 15 per cent $TiO_2$, 80 per cent oxide of iron and 5 per cent gangue; others 40 per cent $TiO_2$, 55 per cent oxide of iron and some 5 per cent of gangue.

By smelting these ores in our electric furnace with addition of carbon in quantity just sufficient to reduce the oxides of iron and not the titanic acid (the last of the two oxides which is reduced in all cases), and operating with a moderate current, we have obtained a regular pig iron containing no or but a few hundredths of 1 per cent of titanium and a slag in which was concentrated all the titanic acid of the ores, that is, with the first ore, some 75 per cent of titanic acid, and with the second some 88 per cent, and practically free from oxide of iron or containing but such small quantities (1 per cent to 2 per cent or thereabout), as are met with in blast furnace slags. This "igneous concentrate," as we have called it, this sort of "artificial rutile," forms an excellent and cheap material to be reduced economically by aluminium. The pig iron smelted like the metal which has been smelted from titaniferous iron ores in the blast furnace possesses valuable properties. At any rate, it commands a price fully as high as that of very good pig iron, which price offsets the expense of the production of the "concentrate" to such an extent that the cost of the latter becomes, to all purposes, nominal.

## NEW YORK MEETING OF THE AMERICAN INSTITUTE OF MINING ENGINEERS

The American Institute of Mining Engineers held its eighty-fifth meeting in New York City from October 13 to 17.

On the morning and afternoon of October 14 sessions were held in Schermerhorn Hall of Columbia University, devoted to the reading and discussion of papers on mining and general metallurgy, and on the morning of October 15 a session in the hall of the American Society of Mechanical Engineers, devoted to the reading and discussion of papers on the metallurgy of iron and steel.

During this latter session the secretary, Dr. R. W. Raymond, made an interesting announcement concerning the result of balloting on the proposed gift of Mr. Carnegie for a Union Engineering Building. He referred to Mr. Carnegie repeatedly as the distinguished fellow member of the American Institute of Mining Engineers. Some doubts had originally been expressed as to the attitude of the Institute of Mining Engineers in this matter for the reason that the Institute had always endeavored to be an *American* institute, representing the total membership and not to benefit specially the New York City members. When, many years ago, the headquarters were transferred from Philadelphia to New York, it had been promised that the Institute would never become a society for the special benefit of New York members. This promise has been truly kept. In fact, when the suggestion was made to open club rooms for New York members, and for other members visiting New York, Dr. Raymond suggested that such a club should not be connected with any national society. From this suggestion resulted the foundation of the Engineers' Club. As this policy had always been followed by the council of the American Institute of Mining Engineers, it seemed doubtful what position the institute would take towards Mr. Carnegie's scheme of a Union Engineering Building.

The council, however, declared heartily in favor of this scheme, and the question of the advisability of the Institute of Mining Engineers joining the other societies in this scheme was submitted to all the members for a letter ballot. Out of about 3500 members, 1600 voted, and Dr. Raymond stated "about 1600 votes were in the affirmative and 5 or 6 voted against it." The argument presented by the latter was that the society had been run so smoothly for so many years that it seemed not advisable to change anything. Dr. Raymond pointed out that this smooth running of the affairs of the society was mainly due to two principles which were always followed, and which should also be strictly adhered to in future. First that the council of the Institute is omnipotent second, that this omnipotence refers only to a very limited circle of duties. Neither the council nor even the society itself is allowed to adopt resolutions for or against, say, the metric system or to adopt rules of standardization. This does not prevent the Institute from having a committee appointed for a discussion of such questions or to discuss it in a general session; but what the Institute is after is the information gathered by such committees or brought out in such discussions, and not the adoption of resolutions. "We do not endorse anybody's theory, we do not endorse our own." The carrying out of the Union Engineering Building scheme will necessitate some changes in the constitution of the Institute of Mining Engineers. They will be submitted to the members at the next general meeting in February, 1904.

On the afternoon of October 15 optional trips to metallurgical plants in the vicinity of New York had been arranged, invitations having been extended to the Institute by the following concerns: The American Smelting and Refining Co., the Balbach Smelting and Refining Co., the Bayonne Refinery of the Standard Oil Co., and the Nichols Chemical Co. Mr. Nichols personally conducted the latter party and his company had arranged refreshments for the visitors. On the evening of October 15 a reception and dance were given at Sherry's. On October 16 an inspection of the Rapid Transit Subway had been arranged for the forenoon and for the afternoon a trip by water around Manhattan Island. On the evening of the same day Dr. G. F. Kunz and Dr. Charles Baskerville presented a paper on "the action of radium, Röntgen rays and ultra-violet light upon minerals" at the hall of the American Museum of Natural History.

In the whole 50 papers were on the programme, of which, however, only a small number were really presented.

The paper that would probably be of the greatest interest to the readers of Electrochemical Industry was by Mr. F. A. Kjellin, of Gysinge, Sweden, on his electric steel furnace at Gysinge, which is a furnace without electrodes, the charge forming the single secondary turn of an alternating current transformer. In the absence of the author it was read by Dr. Leonard Waldo, who explained that for iron and steel an arc furnace gives too high a temperature, while with a resistance furnace with electrodes impurities are introduced into the charge from the electrodes. The chief features of a resistance furnace based on the induction principle are freedom of the charge from contact with any form of fuel, and from any contaminations from the electrodes. Mr. Kjellin's paper itself did not seem to contain much that has not been already published in this journal (see Electrochemical Industry, December, 1902, p. 141; July, 1903, p. 376; September, 1903, p. 462).

Other papers of interest to our readers are "Steel for 'Third Rails,'" by J. A. Capp; "Metallurgy of the Homestake Ores," by C. W. Merrill; "The Cyanide Plant and Practice at the Ymir Mine, West Kootenay, B. C.," by E. C. Holden; and others. Since limitations of space prevent us from giving abstracts of these papers in the present issue, we will reserve them for our next number.

## ALUMINOTHERMICS.

By Hans Goldschmidt, Ph. D.

At the request of the editor of Electrochemical Industry, the author has written the following article in which the practical applications of "aluminothermics" are chiefly considered, to supplement an article of Dr. G. P. Scholl (page 175 of the January issue of this journal), in which mainly the thermochemical side of the question was discussed on the basis of former publications of the present writer.

Up to the present, aluminothermics has been commercially successful in two fields; first, in the production of metals, free from carbon, such as are needed in the manufacture of certain special steels; second, for welding purposes with the aid of thermit. Recently a third application has been developed, namely, the improving of iron and steel castings.

### Production of Pure Metals Free from Carbon.

Originally the aluminothermic reaction was made use of only as a means for preparing pure refractory metals, for producing chromium, manganese, ferrotitanium, ferroboron, etc. People not familiar with the subject may perhaps be surprised that such a simple reaction as the aluminothermic one had to undergo a special extended practical development. Yet in the case of every metal the evolution of the aluminothermic method of making the pure metal in uniform quality and with a high efficiency, involved very considerable work, which is not surprising if the reactions taking place in such a process are considered in detail. For this reason

FIG. 1. RAILWELDING ON TRACK (DRESDEN, 1903).

it was specially gratifying to the author, that when, several years ago, he showed to Prof. Moissan the method of producing on a large scale chromium and manganese, free from carbon, the first question which the latter asked was how many years of work had been required to render the reaction so simple and smooth.

All thermit mixtures consist of nearly equivalent quantities of a metallic oxide and aluminum, and what is generally called "thermit," consists mainly of a mixture of oxide of iron and aluminum, as anybody who should be interested in preparing it himself can easily find out.

Comparison may be made with other reagents which also yield an exothermic reaction, although with a quite different effect. Gunpowder and dynamite are, for example, of very simple composition and their manufacture is to some extent easy. Many anarchistic crimes were possible only for the reason that it is not very difficult to make dynamite. But while such reagents made by laymen may explode, a regular, sure effect, as is required for engineering purposes, cannot be guaranteed. The technical manufacture just of dynamite is a very subtle matter.

The conditions are similar with gunpowder. Boys make powder by putting saltpeter, sulphur and charcoal together and really thus get a mixture which burns, but it has not the explosive value which meets modern technical requirements. It is well known that in all such mixtures the physical nature and the distribution of the materials is of main importance, so that even with the same, or with nearly the same, chemical composition very different effects may be produced. We may refer to the different kinds of gunpowder according to the different sizes of the grains. The main requirement is the uniformity of the product. Similarly, the manufacture of a technically useful thermit required much work; especially details of a physical nature had to be studied and had to be continually watched during manufacture, while the design of special machines and devices also became necessary. Most of these details cannot be expressed in form of prescriptions or briefly described, nor are they of general interest.

Besides the pure metals and alloys formerly made in this way, it has recently become possible to produce pure fused molybdenum. It is a metal of a gray color, like steel, and of dense structure. It contains as chief impurity about 1 or 2 per cent of iron, besides very small quantities of silicium, so that its purity is 98 to 99 per cent. Molybdenum was

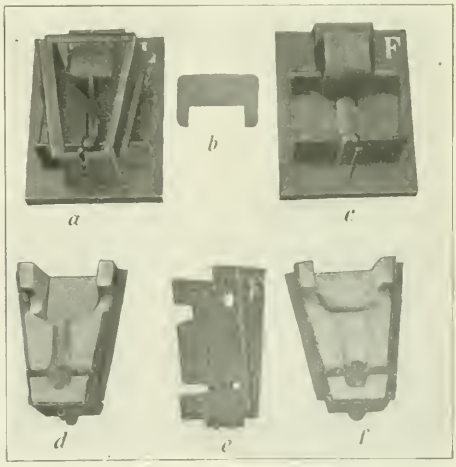



FIG. 2. RAILWELDING PROCESS.

*a* Model for the hip side with mould shell. *b* Appliance used when ramming the sand in. *c* Model for tread side. *d* Finished half of mould for hip side. *e* Half of mould shell for tread side. *f* Finished half of mould for tread side.

formerly made only in powdered form, by reduction of the acid by carbon (like tungsten) and has found application in the manufacture of some special steels. The author now produces also a tungsten alloy of high percentage, with the specific gravity 14.5, which may be easily machined and is very strong. It is used for ballistic purposes.

Since recently metallic silicon with a purity of 98 per cent has been placed on the market at a low price, it appeared promising to substitute silicon wholly or partly for aluminum for the purpose of the thermic reaction. The high value of the heat of oxidation of silicon seemed to justify such hopes, moreover the possibility seemed promising to get by the simultaneous use of silicon and aluminum more easily fusible silicate slags. However, the result of these experiments was negative. For instance, equivalent mixtures of oxide of iron and silicon or of oxide of nickel and silicon, cannot be ignited like thermit.

Even here peculiar, however, are mixtures of both silicon

and aluminium with oxide of iron. Even if only 10 per cent of an equivalent mixture of silicon and oxide of iron are added to ordinary thermit, this addition delays the progress of the reaction to such an extent that this thermit becomes unsuitable for welding purposes. While the temperature produced by the heat of oxidation of aluminium starts the reaction between the silicon and the oxide, yet the latter reaction is considerably slower than the formation of $Al_2O_3$. The slag is somewhat more easily fusible, but the delay of

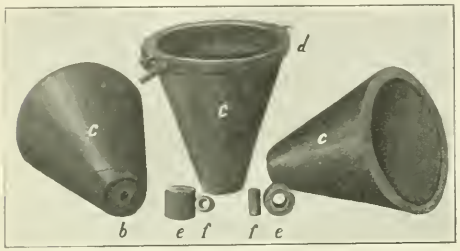



FIG. 4.—CONICAL CRUCIBLES LINED WITH MAGNESIA.

*b* Flow hole. *c* Sheet-iron shell. *d* Protecting ring. *e* Large magnesia stone. *f* Small magnesia stone (thimble).

the reaction—and the loss of heat due to this delay—more than counterbalances this gain.

The result will be similar, if one tries to aid the formation of $Si_2O_3$ by larger additions of silicon, and the reaction even stops entirely if about 50 per cent of silicon are added: a sintered mass is then formed. It is possible to aid the reaction somewhat by means of external heating, but the improvement is only slight and does not lead to a practical success.

External heating, as an accessory to extremely smooth aluminothermic reactions, is essentially nonsensical. This is evident, because, in view of the heat evolved in the few seconds by the reaction itself, an appreciable supply of external heat is impracticable even with the aid of electrical energy. Reference may be made to the calculation of the "energy density" of thermit (*Zeit. f. Anorgan. Chemie*, 1902, September 28, and Electrochemical Industry, January, 1903, p. 177): the figures there mentioned show the uselessness of an external supply of heat.

FIG. 3.—WELDED RAIL.

It is also useless to preheat the mixture in order to start the reaction. It is possible to always add new material to the mixture after the reaction is started, so that the glow is covered. By this means the mixture is not only completely dried, but strongly preheated, before the reaction starts, yet an acceleration of the reaction of the thus preheated mixture is not observed.

### Thermit for Welding.

The large field of welding processes with the aid of thermit—which is at present the most important application of aluminothermics—has been considerably broadened in recent years with respect to the evolution and application of the methods for such purposes. Especially the welding of tramway rails (Fig. 1) by the thermit process has come into a steadily extending use, and by many tests—which have been conducted with great care, especially in England—this method was found to be the best and cheapest at present available. A special committee, appointed for an investigation of the process a year ago by the city of Leeds, in England, has arrived at this result, not only by special stress-strain tests, but

FIG. 5.—RAILWELDING WITHOUT CLAMPS.

by a visit to various roads in Germany (in Dresden, Berlin and Brunswick), in which rails welded together by the thermit process had been in use for about three years. It was found that the welded joints could not be distinguished from the rail itself. In Leeds several miles of rails have already been welded together, and a larger number of other cities,

FIG. 6.—STERNPOST OF S. S. SEVILLA WELDED IN DRY DOCK.

like Glasgow, Nottingham, etc., are also introducing the system. After nearly four years of constant use, the general applicability of the thermit process is now to be considered as proven so that some roads use it as the only method of joining rails together. For instance, a large English com-

pany is now welding tramway rails in Singapore, to an extent of twenty-five miles, by the thermit process.

The characteristic features of the process are the simplicity of operation and the absence of any larger apparatus. There are required only rail clamps, a crucible with 15 to 20 lbs. of thermit and a small mould which is placed around the joint. Experience has shown that welding with thermit is performed more quickly than fixing fish-plates with copper bonds.

An exact description of this method of welding rails may now be given. For every cross-section of rail a special model is made which serves for making the mould to be placed around the joint. By a very great number of tests

FIG. 7. BROKEN STERNPOST OF S.S. SABINO (TRIESTE) WELDED WITH THERMIT.

the required thickness of the small channels between rail and mould wall has been determined. The dimensions of these channels vary between about 10 and 30 mm. (0.4 and 1.2 inch) thickness and 30 to 100 mm. (1.2 to 4 inches) length, they are different according to the various dimensions of the head, web and foot of the rail cross section (Fig. 2). The thermit-iron which first runs out of the crucible, flows around base and web and melts them together. For this purpose narrow channels are preferable. Simultaneously the molten slag flows around the head of the rail and heats it up to welding temperature. The whole cross-section of the rail is thus uniformly heated to welding temperature, so that a bending of the rail ends is prevented. Finally, a few minutes after the reacting mass has flown into the mould, the set-screws of the rail clamps are drawn together by one turn (which corresponds to about 10 mm. or 0.4 inch) and an absolutely uniform weld is thus obtained. The joint is even

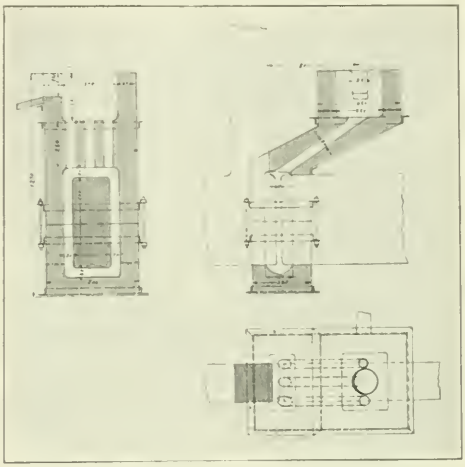


FIG. 8. MOULD FOR SEVILLA REPAIR.

stronger than the rail on account of the welded mass of malleable thermit iron. (Fig. 3.) The small up-set of the joint of the rail is filed off by hand or removed with a grinder.

FIG. 9. BROKEN STERNPOST WELDED ON DUTCH STEAMER.

The joint will become permanently invisible after a few cars have rolled over it.

From the model, which is mostly made of aluminium in order to be handy, the mould is made in the ordinary manner known to every moulder. Since no artistic castings are re-

quired, the moulding can be made by any young workman. Any moulding material may be used which is suitable for steel castings, for instance, a mixture of 80 parts of sand with 20 parts of china clay, or a mixture of yellow clay and sand in equal parts. The drying of this mass is accomplished in

FIG. 10.—WROUGHT-IRON TUBE BENT AT WELD WHILST COLD.

about four hours, at a temperature of about 300 to 400 degrees Centigrade. The mass had best be stamped into a sheet-iron box placed around the aluminium model. This box serves for a very great number of weldings. The mould is fastened to the rails and any apertures are closed by clay, etc. Its cost is only a few cents.

Before welding, the rail ends are slightly preheated with a soldering lamp, or some kindling wood, to facilitate the removal of dirt and rust, which is done with the aid of a wire brush. The use of a sand-blast has been found superfluous.

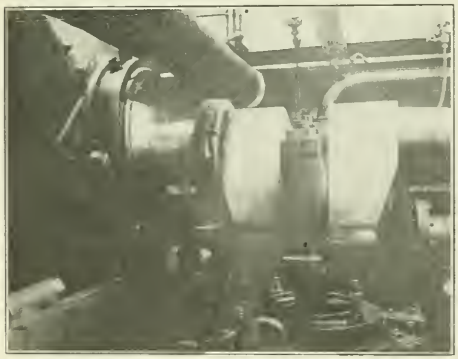


FIG. 11.—CRANKSHAFT REPAIRED ON BOARD A RHINE STEAMER.

The cross-sections to be butted are cleaned with a file. This is all the preliminary work required and does not take much time.

The welding of the rails is always done by the same company which lays the rails, since the method of welding is easily mastered by any intelligent workman after he has made a few weldings. The most important point is that the rails are placed in the true, straight line to avoid welding in deviations; this has, of course, nothing to do with the welding process itself. True, a certain accuracy is required during the welding process, but that it is not difficult is proven by the fact that quite a number of companies have quickly familiarized themselves with the process.

The crucibles consist of a sheet-iron mantle with a magnesite lining. By placing a cast-iron cone into the mantle, a free space is formed between cone and mantle which is filled with heated magnesite tar. The crucibles with the cone are placed for about two hours into a furnace, and heated up to red heat and are then ready for use. The large tramway companies make these crucibles themselves. They serve for about twenty-five castings, so that the item of crucible wear and tear per joint is insignificant. In the bottom of the crucible there is a perforated cone of magnesia stone. It contains a second one which is also perforated and serves as "thimble." The latter may be easily replaced after a number of castings. (Fig. 4.) Between both cones of magnesia stone there is only a layer of paper. By the use of the thimble it is possible to render the diameter of the flow

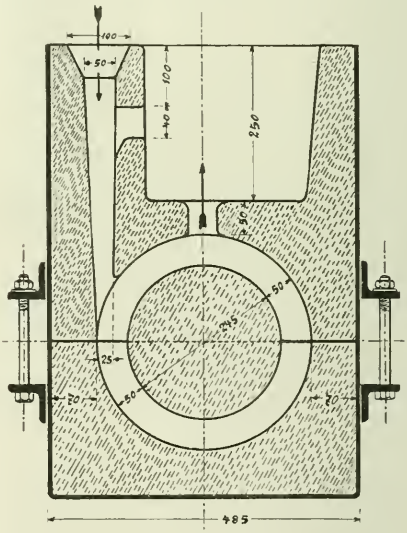



FIG. 12. MOULD FOR REPAIRING BROKEN SHAFTS.

nearly constant, equal to about 0.4 to 0.7 inch, which is important for the uniform flow of the molten mass.

The quantity of thermit required is different for each rail cross-section and depends on its weight and its dimensions, and the composition is also slightly varied according to empirical rules, in order to obtain a uniform welding joint in all cases. This quantity of thermit, in a sealed bag, labeled with the number of rail cross-section, is furnished to the tramways companies under the name of "welding portion." Since the latter generally make their own moulds and often their own crucibles, the welding portions and the rail clamps are the only things to be bought.

In certain cases, even the rail clamps are not required, as, for instance, when it is required to weld old rails together which had already been used. (Fig. 5.) After removing the loosened fish-plates, a proper mould is placed around the joint and the reacting mass is passed into it from the crucible. In this case the heads of the rails are not welded together, or only partly, but the bases and webs are completely welded together up to nearly the rail head. Moreover, the joint is strengthened by the thermit-iron around the base.

This method, while giving a perfectly reliable joint, requires less time, because no rail clamps are used, nor has the up-set to be filed off. A heating of the rail heads by the slag to the temperature of welding must also occur in this

case, in order to prevent a bending of the rails. If there is a space between the rail ends, it must be filled, before welding, with a shim. The shims may be pressed between the ends of the rails, for instance, by raising the rail ends by means of a wrench, in order to broaden the distance between the rail ends at the top. If this is done, it is often possible to produce a welding together of the rail heads. This is always preferable, as the thermit process is specially elegant for the reason that after the rail heads are welded together the joint is invisible.

For this reason, on old tracks which need repairing (of course, only on such tracks where the wear and tear of the joints has not gone too far), it is generally tried to weld by the following method: The rail clamps are fixed on the rails and by drawing the screws backwards, the space between the rail ends is enlarged by 8 to 10 mm. (0.3 to 0.4 inch). The thickness of the shim exceeds by 8 to 10 mm. (0.3 to 0.4 inch) the original space between the rails. After the run of the molten thermit is completed, the rails are then butted together, as in the ordinary welding process, but care is to be taken that the length of the embedded track is not shortened.

FIG. 13.—WELDING OF A CONNECTING ROD.

If the track is laid in a paved street, it is necessary to loosen the pavement sufficiently before and behind the joint. With very firmly embedded rails this method is, however, impossible, and no welding together of the rail heads can be made. Of course, in considering the advisability of welding old rails together, the special conditions of each case must be taken into account. It has been undertaken with the best success, for instance, without rail clamps in Brunswick, and in several places in France, like Rouen, Havre, etc.; with clamps in Italy, for instance, in Genoa, even with a rather firmly embedded track.

A large number of tests were made by the author as well as by tramway companies in order to determine the strength of the welded joint, and to see how the portions of the rails, heated by the thermit, are thereby influenced. The strength produced in the head of the rail by welding is about 80 per cent the strength of the material, even with very hard material. A test, recently made by a company, gave 87.75 per cent of the strength of the original material.

Test pieces for tension tests were also cut from rail sections which had undergone a thermit-iron casting in the same way as though a welding should be made, in order to give the piece the same heat to which the rail ends are exposed during the welding process. Since the whole welding zone is only 6 inches long, while the test rod had a length of 8 inches, the whole heating zone was inside the test rod.

The figures which refer to a non-heated portion of the rail

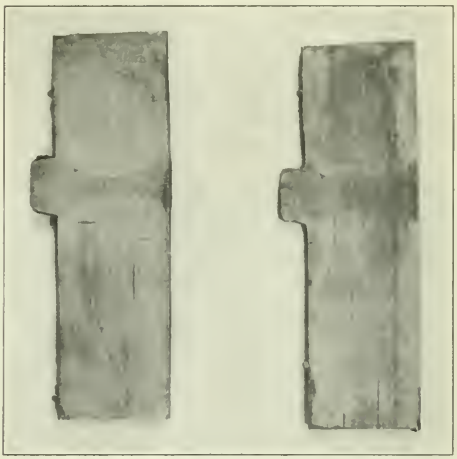


FIG. 14.—INTERMEDIATE WELD OF RECTANGULAR RODS (140 mm. by 140 mm. or 5½ in. by 5½ in.)

and those which refer to portions heated by thermit to a welding temperature, agree with each other nearly exactly, which proves that the rail material does not become softer or harder, due to the welding with thermit. Practical experience has confirmed this result. In six analogous tests the following figures were obtained:

The strength of the original material varied between 68.9 and 84.7 kiligram per sq. mm. (98,000 and 120,000 lbs. per sq inch), while the elongation was between 8 and 15.5 per cent For the six test pieces, around which thermit had been cast, the strength varied between 66.2 and 80.8 kilogram per sq mm. (94,000 and 115,000 lbs. per sq. inch), while the elongation varied between 9.5 and 12.5 per cent. The average values were about the same.

A large number of test pieces were taken from head, base and web of rail joints, the cross-sections of which had been welded together. The strength varied here between 55.6 and 67.8 kilograms per sq. mm. (79,000 and 96,000 lbs. per sq. inch). The average value is above 62 kilograms per sq. mm. (88,000 lbs. per sq. inch). It follows that only the very short welding section itself (a piece of 1 to 2 mm. or 0.04 to 0.08 inches length) has undergone a slight decrease of strength due to the welding processs. The rail material, therefore, is not changed in the neighborhood of the joint, while the latter, by the welding process, is made thicker than the rail itself.

If the rails, after having been welded together are crushed or broken, the breaking point is always outside of the welded joint, and mostly even outside of the welding zone. An ex-

planation for the excellence of the joint, obtained with the thermit process, is that the welding takes place under complete absence of air, and that an always uniform quantity of heat—which does not depend on the welder—is supplied to the welding point by the exactly weighed "welding portion."

A further application of thermit is on electric railways of the third rail type for joining the third rail together. It is well known that copper bonds are unsatisfactory for this purpose, since a good, permanent joint cannot be guaranteed. The transition resistance increases with the time and requires repeated and extensive repairs. Simpler, more reliable, and at the same time considerably cheaper is the method of welding rails; the weld may only be partial. On the suburban road from Berlin to Grosslichterfelde the Union Electricitäts Gesellschaft of Berlin has recently used this method on a track length of about 22 kilometers (13.6 miles). In this case an electric connection of three lengths of rail (45 meters, or 148 feet) has been accomplished by welding on a small head of thermit-iron. An ordinary fish-plate strengthens the mechanical connection of the rails.

### Repairs of Castings.

Recently the use of thermit has become very important for the repair of broken stern posts of steamers. (Fig. 6). To replace a broken part by a new one is not only expensive, but what is of still greater importance, much time is lost, while the steamer cannot be used, but is in dock eating up interest. By means of a repair with thermit, the time required for the repair may be reduced from months to a few days, or to a still shorter time. The repair which otherwise requires several ten thousands of marks (10,000 marks = $2,500) can now be made for a few hundred marks by the longshoremen on the dock, because the use of thermit is very simple and may be quickly learned. (Fig. 7).

Even great repairs in which several hundred kilograms (1 kg. = 2.2 lbs.) of thermit are used in one reaction, are very simple. The principal requirement is to apply a mould of proper dimensions. (Fig. 8). That this is easily made from given models, has been proven by several very successful weldings of stern posts in Holland, which were made in loco according to brief instructions received by mail. (Fig. 9).

### Welding of Wrought-Iron Tubes and Solid Rods.

Reference may also be made to the well-known method of welding wrought-iron tubes together with the aid of thermit. The number of such weldings which have actually been made is estimated at 30,000 to 40,000. This method of thermit welding is cheaper than a good flange-joint, and may be made even at a place which is not easily accessible. It is of special advantage for tubes under high pressure or for the transport of liquids which attack nearly every material for packing, such as alkalies, petroleum, etc. (Fig. 10).

In these cases a pure butt welding of the tube ends is made, a small mould of sheet-iron being applied, surrounded by sand. From a crucible the molten thermit is poured into the mould. The corundum flows out first, so that the tube is at once surrounded with a thin layer of corundum about 1 mm. (0.04 inch) thick, so that the thermit-iron which flows out afterwards cannot touch the tube directly and therefore cannot melt it through. For every size of tube up to about 6 inches a simple table has been worked out from which to find at once the dimensions of the mould, its distance from the tube and the quantity of thermit to be applied.

Similarly, in special cases, a butt end welding of solid rods may be made. For this purpose also a similar table has been worked out.

It is especially remarkable that the aluminothermic butt end weldings are of excellent quality. We have already mentioned above that even hard rail material gives a good weld.

FIG. 15. REPAIR OF A LARGE ENGINE WHEEL.

In the following table the results are given of four 1½ inch rectangular rods of somewhat soft material of Martin cast-iron welded together by thermit. The breaking point of normally decreased diameter was in all cases outside of the welding zone:

| Rod 40 by 40 mm. (1½ by 1½ inch) | Analyses. | | | | Breaking Point in kg. per sq. mm. | Elongation in ℓ Referring to 200 mm. Original Length. |
|---|---|---|---|---|---|---|
| | C. | Si. | Mn. | S. | | |
| I | 0.10 | 0.05 | 0.27 | 0.06 | 44 | 20 5 |
| II | 0.11 | 0 04 | 0 37 | 0.06 | 41.7 | 20.5 |
| III | 0.08 | 0.08 | 0.33 | 0 07 | 44.4 | 22 |

In most cases in which broken rods or shafts are to be welded together with thermit, the pure butt end welding will not be used, but a so-called automatic method as is used for rail welding. (Figs. 11 and 12). A table has been worked out which gives the quantity of thermit required and the

dimensions of the mould, which may be made from 80 parts of sand with 20 parts of coalin.

Instead of merely running metal round broken shafts, in many cases the so-called combined intermediate and annular welding method may be used. In this case the shaft ends are fixed at a distance of 10 to 20 mm. (0.4 to 0.8 inch) and a proper mould is then applied. The advantage of this method is that the joint becomes a more intimate one, since the thermit-iron flowing through the intermediate space dissolves a part of the shaft ends so that these are firmly welded together with the intermediate casting. In this case the length of the thermit-iron ring is only about one-half that required in the former case. A table giving the exact figures for the thermit required and for the dimensions of the mould has been worked out for this purpose.

### "Anti-Piping" Thermit for Improving Iron and Steel Castings.

The third field of application mentioned in the introduction of this article is for improving iron and steel castings. The

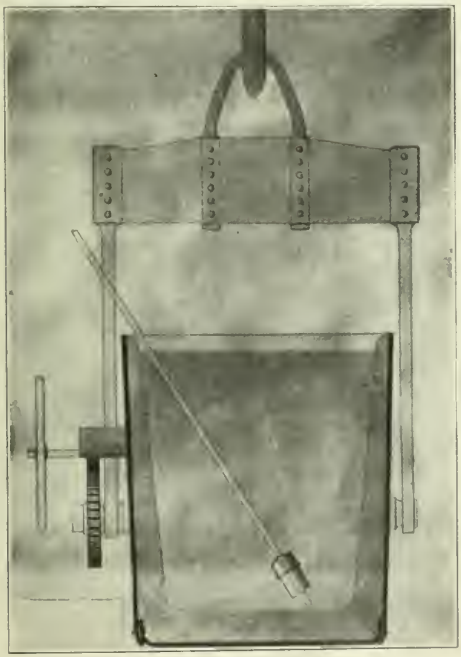


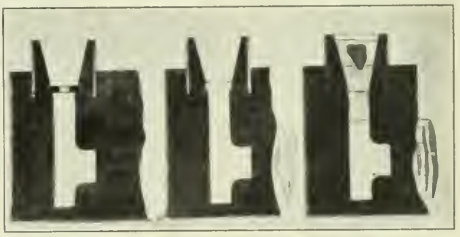
FIG. 16.—SHANK WITH TITANIUM THERMIT BOX IMMERSED.

methods used in this field have been worked out by my associate, Chief Engineer Mathesius.

According to the principle common to all applications in this field, the thermit is brought to reaction below the surface of the metallic bath. At a point within the bath a high temperature is therefore produced. For this purpose the thermit is filled into a tin box which is fixed at the end of an iron rod, and by these means the box is held under the surface of the molten metal. For further details the reader is referred to the accompanying illustrations. (Fig. 16).

In the first line this method is used in crucibles with molten cast-iron. In these cases not ordinary thermit is used, but a kind which gives off an alloy of iron with titanium, so that a quantity of titanium is introduced in statu nascendi into the cast-iron. The author has formerly applied this titanium-thermit (really ferro-titanium-thermit) directly to the surface of the molten cast-iron. Good results are also obtained in this way, but the new application of bringing the thermit below the surface of the bath is more reliable and more economical, smaller quantities of thermit being sufficient. That the thermit really burns off without unburned portions coming to the surface, is explained by the fact that the slag formed during the reaction surrounds the unburned particles so that they stick to the iron rod. The tin box is dissolved almost immediately and serves only as a means to hold the thermit together before the reaction starts in the metal bath. The reaction in the cast-iron bath lasts only one or two minutes and produces a very complete stirring of the whole bath. A kind of poling of cast-iron is thus produced, gases and particles of slag being driven upwards, so that the iron appears to be heated to a higher temperature. The real increase of temperature is, of course, only small, since according to the size of the crucible of 200 kilograms (440 lbs.) up to several thousand kilograms, only ¼ to 1-16 per cent of titanium is used. The introduction of titanium is made in order to bind small quantities of nitrogen. According to the results so far obtained, a small addition of titanium to cast-iron seems to increase its tenacity and to produce a finer grain.

This method has been applied with the best success by several foundries, and is of special use in plants in which the production of castings free from pores is of special importance, that is, in mills in which machine castings of all kind are made.



BEFORE DURING THE CASTING AFTER

FIG. 20.

By the reaction described it is not only possible to produce a casting absolutely free from pores, but it is also possible to introduce into the crucible desirable additions of other materials, for instance, of ferro-manganese. After such a so-called "box reaction" has been carried out, the manganese—which may, for instance, be assumed as 1 present—is found uniformly distributed in the casting. The same method may be used for an addition of nickel for making crucibles used in evaporating caustic alkalies in the chemical industry. In this case it is better to use the nickel in form of nickel thermit, which has been ignited previously in another ladle, and is then poured into the crucible together with the slag. The uniform mixing of the nickel is then produced by means of a "box" reaction. Nickel thermit, containing 60 per cent of metallic nickel, is used in the proportion of about 1 per cent of the contents of the ladle, and with such nickel addition about 50 per cent more charge can be treated than without nickel.

Another application of the so-called "box reaction" is important for steel castings, and especially for casting large steel ingots, to prevent the familiar phenomenon of piping. In the heads of such blocks hollow spaces are found which mostly cause 30 to 40 per cent of loss. (Fig. 17). Many means have been tried to overcome this disadvantage. Only recently a method has been worked out in which the whole block after the casting is completed is put under a very strong pressure. On account of the large apparatus required, this method is

very expensive, but it shows how important it is considered to overcome the above disadvantage.

The thermit process as used for this purpose consists in introducing a box of so-called anti-piping thermit into the block with the aid of an iron rod, in exactly the same way as described before. According to the size of the block, the box is suspended about one meter (3.3 feet). (Fig. 18.) The reaction is completed in this case in a few seconds. The box is introduced, of course, only after the piping has been formed, that is, after about 15 to 20 minutes. The head layer, which has already become solid, is broken through for this purpose. Immediately after the reaction is completed, steel, which had been kept prepared for this purpose, is poured into the open hole. The method is really very simple, and one learns very quickly at which time to introduce the box. Moreover, the method is very cheap, only about 5 kilograms of thermit being required for blocks of 10 to 20 tons of weight. In Fig. 19 a block is shown which had been treated by the method of Mr. Mathesius. After the treatment relatively very small pores were found, and only in the upper part of the block as shown in the illustration, so that the loss was only very few per cent. The method has also been applied for very large steel castings to revive steel which had become plastic in the runners. Fig. 20 shows a steel casting (large cogwheel). In this the anti-piping thermit is placed at the bottom of some runners in an annular box with concentric walls, containing about 2½ lbs. of thermit. There is in this case no need to thrust the box in by means of an iron rod. The piping will not protrude into the piece, but will be kept right at the head of the runner. The difficult operation of casting long stern posts of vessels can be facilitated by inserting in several places boxes of this thermit. On account of the long way the steel has to travel it has a tendency to grow plastic. But coming into contact with thermit, its temperature, and thereby its fluidity, is increased again.

FIG. 17. STEEL BLOCK SHOWING DEFECTIVE HEAD (PIPING), WITHOUT ANTI-PIPING THERMIT.

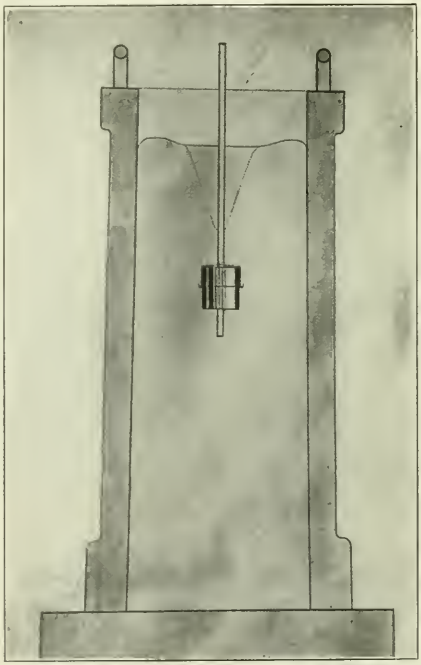


FIG. 18. STEEL BLOCK WITH BOX OF ANTI-PIPING THERMIT IMMERSED.

FIG. 19.—10-TON STEEL BLOCK AFTER HAVING BEEN TREATED WITH ANTI-PIPING THERMIT.

Conclusion.

While the thermit methods have found a very extended application and rapid development in most European countries, and have also been applied in some foreign countries, especially for making repairs, it is surprising that they have been used in practice to a comparatively very small extent in the United States. While the metals free from carbon, especially pure chromium, have found here a ready market, yet the welding of rails by the thermit process, which should be of the greatest importance to this country has not yet been tried.

This may be due to the fact that the keynote of the industrial development of the United States is specialization, while the thermit methods are of a very manifold nature, as was shown in this article. The production of pure chromium, etc., is of importance for the steel industries. In view of the many uses of manganese, free from carbon, the thermit process should become equally important for the manufacture of alloys of copper, nickel and bronzes. But besides these metallurgical applications, the thermit process is useful in various mechanical operations, for making repairs of all kinds, for instance, in railroad repair shops, in machine factories, and especially in the navy. The field of welding wrought-iron tubes may be considered again as a separate one. Finally, by the use of anti-piping thermit for improving castings, a further successful field has been opened.

On account of these reasons the introduction of thermit and its applications has been behindhand in the United States. The author hopes, however, to be shortly in a position of establishing a suitable organization in this country which will enable the introduction of the various applications of thermit into general use. In view of the engineering talents of the American people, it may be expected that the thermit methods will find a special wide application in this country after a suitable beginning has once been made.

## NOTES ON A CLASSIFICATION OF ELECTROCHEMISTRY.

By Clinton Paul Townsend.

(*Concluded from page 379.*)

### Aqueous Bath Pigments, White Lead.

The pigment processes, including the production of white lead, are essentially cyclical in character, the pigment being usually derived from the anode by its solution and subsequent precipitation, as oxid, hydroxid, sulfid, carbonate, neutral or basic, chromate, etc. Consequently, in theory at least, the process may continue indefinitely provided the bath be suitably supplied with water and the radical of the precipitant. Since this cyclical character is quite generally characteristic of electrolytic methods which yield insoluble products, it is feasible to group all such under this title. The great number of suggested methods for the electrolytic production of white lead renders it advisable to segregate them.

### Aqueous Bath, Platinum and Palladium.

Protective coatings of these metals are frequently applied, the palladium coating being found particularly suited for reflecting surfaces. The electrolytic methods for the production of platinum black are well known, as also the peculiar solvent effect upon platinum of the alternating current in certain electrolytes.

### Aqueous Bath, Reduction by Couple.

This title covers the application of the couple for purposes of reduction, the principal technical use being the separation of gold from extremely dilute solutions; in such cases the couple is commonly arranged as a filter. The use of the couple for organic reductions is also common. The term is here given its widest significance.

### Aqueous Bath, Refining Metals.

The sub-division of this, the most important technical application of electrolysis, may be extended as desired. Copper, silver and gold are now electrolytically refined in this country, and carefully elaborated methods have been described which are applicable to nickel, lead, tin, antimony, zinc, bismuth, and even iron. At the present time attention is being chiefly devoted to the parting of nickel and copper from bessemerized matte or composite metal.

### Aqueous Bath, Refining Metals, Regenerating Electrolyte.

The regeneration methods are not necessarily electrolytic, but relate to the purification of the electrolyte, and generally to the elimination of arsenic from copper refining solutions.

### Aqueous Bath, Silver.

The disposition of the metal, voltameter constructions, etc.

### Aqueous Bath, Sulfates.

The electrolytic methods relating to sulfates comprise the purification of sulfuric acid, the electrolytic oxidation of sulfur and sulfurous acid, and the production of persulfates.

### Aqueous Bath, Tin, Treating Tin Scrap.

The deposition of the metal is, in a commercial sense, quite overshadowed by the recurrent proposition to recover the metal from tinned scrap. The patent and other literature relating to this subject is extended, and recent methods offer promises of commercial success.

### Aqueous Bath, Zinc.

Under this title are included the efforts toward electrolytic "galvanizing" of iron; the study of the problem of sponge; the electrolytic behavior of chlorid solutions which offer important advantages for the separation of the metal from ores, and the reversal of certain primary cells.

### Asymmetric Cells.

The "electrical valve action" of cells having an electrode of aluminum, and its application to the rectification of alternating currents. These cells employ both aqueous and molten electrolytes.

### Carbon.

The conversion of carbon at high temperatures into graphite and crystalline forms is appropriately classified with electric furnace methods. There remains, however, an interesting literature of which examples are the researches upon carbonaceous deposits from aqueous solution, and the subject of the carbon cell.

### Depolarizing.

Depolarization is either chemical or mechanical, and includes all methods and devices for removing gases from the electrodes, whether by causing them to enter into chemical combination, as in the oxidation of hydrogen by copper oxid, or by detaching them by the movement of the electrode or electrolyte or other mechanical means or by the diminution of the gas pressure above the electrolyte.

### Diaphragms.

The character and composition of a diaphragm is often so closely related to the function to be performed that it is of interest only in connection with a particular method, and is best classified therewith. In the majority of cases, however, descriptions of diaphragms are with advantage cross referenced to the present title, always with a note regarding the purpose for which they are used.

### Electric Furnaces.

The class of electric furnaces includes those constructions whose primary purpose is to subject materials to heat developed by means of the current, the constructions wherein the heat development is supplementary to the electrolytic effect being referred to the title "fused bath." The temperature is usually but not always high, the facility of regulation being an advantage of electric heaters no less important than their capability of affording high temperatures. It is usual to distinguish these furnaces as arc and incandescent, and to further subdivide the latter class according to whether the heat development occurs in the charge or product, or in a resistance body in proximity thereto. Such classification is often serviceable, but since this class deals exclusively with structures, which may be capable of several modes of operation in accordance with the position of the electrodes, the character of the charge, etc., it is of little value in this connection. The class deals largely with the more generalized structures, the furnaces intended for a specific purpose, as the production of carbids, of graphite, of phosphorus, etc., being classified with the corresponding methods.

### Electric Furnace Processes.

These processes depend upon the heat effect of the current and include reactions which are rendered possible by simple rise of temperature, as distinguished from those in which the electrolytic effect governs. This distinction is in the main a sharp one, although certain methods, as in the production of phosphorous, fall into both classes, the element being in certain cases evolved by the electrolysis of molten phosphides, although in general distilled from a charge containing carbon

The titles of the several subclasses, defining each by its product, are so distinctive as to require no comment. In a general way they represent the commercial applications of the electric furnace, or those applications which possess a distinct literature. The residual class, however, is a large one, and includes such important applications as the fusion and volatilization of metals and compounds, the production of glass, the formation of compounds containing oxygen by reaction with metal vapors, the production of borides, selenides, etc. Under the subclass "diamonds" may be included not only the theoretically interesting researches relating directly to this subject but such methods as that of Maxim for the production of hard forms of carbon, and the observations of Ludwig on the behavior of carbon under conditions of extreme pressure and temperature

### Fused Bath.

In the processes which depend upon the electrolytic decom-

position of a molten electrolyte, it is usually essential to develop the heat necessary for the fusion by means of the current itself. This internal heat development possesses the very important advantage of permitting an efficient protection of the containing vessel, either by means of a suitable refractory lining or by a crust of the solidified electrolyte. For constructions of this kind, in which the current performs a double function, the very appropriate name "electrolytic furnace" is now widely used. In certain cases, however, it is still economical to apply heat externally to effect the fusion, so that it is desirable to use here the broader term "fused bath," and to segregate therefrom the two great industrial applications depending, respectively, upon the separation of aluminum and of sodium. The residual class is varied and important, the literature touching the majority of the metals and a wide range of ores and even extending into the organic field.

### Fused Bath, Aluminum.

For the sake of unifying and completing this important subject, the methods of purifying bauxite, of preparing alumina for use, and similarly related matters are included with the electrolytic separation of the metal.

### Fused Bath, Sodium.

The recent great development of a commercial method for the preparation of caustic soda from lead-sodium alloys produced from fused electrolytes, renders it advisable to construe this title as covering the production of the metal, its alloys and compounds.

### Electrolysis Influenced by Magnetism.

The properties of iron electro-deposited in a magnetic field have been carefully studied, as have also the variations in character and distribution of the deposit. In addition, certain technical advantages have been alleged to follow the use of magnetism in conjunction with electrolysis, as, for instance, the amelioration of copper and nickel deposited upon magnetized cathodes and the more rapid oxidation of sodium from mercury-sodium alloys in presence of a magnet. In certain cases also a purely mechanical effect is obtained, as when iron articles are supported by magnets in the plating bath, or the circulation of a mercury cathode is accomplished by means of a magnetic field. The abundant literature of electrolytic conduction without electrodes may also be classified under this title.

### Ozone.

The production and application of ozone. The methods depend upon the use of the high tension discharge, and the electrolytic decomposition of certain solutions, particularly such as contain highly oxidized compounds. The ozonizers using the silent discharge are practical and their construction has reached a highly developed state, although, of course, the actual efficiency is low.

### Printing Processes.

"Printing with ink," as it is generally called, usually consists in the topical development of a color by means of the oxidizing or reducing action of the current upon a suitable compound saturating the paper or fabric, and usually employed in conjunction with an electrolyte capable of furnishing hydrogen and oxygen at the respective electrodes. As will be obvious, there is no distinction in kind between printing and dyeing methods operated according to this principle, the effect depending merely upon the use of type or an appropriate stencil for the electrode and the selection of a compound to give the color desired. In some cases the metal of the electrode enters into the compound, this modification being obviously undesirable. An extension of the principle leads to the water marking of paper, or to the water-proofing of fabrics by the incorporation therewith of electrolytically produced oxids. Totally different methods are those which depend upon the electrolytic production of printing surfaces for planographic work, certain electro-deposits, and particularly zinc, having been found eminently suitable for this purpose.

### Purifying Liquids.

The purification of water by means of soluble anodes capable of yielding insoluble hydroxids, iron, zinc and aluminum, being examples, is rapid and complete, and possesses the advantage over most chemical methods that after separation of the coagulant no extraneous substance remains. In addition, a sterilizing effect due to the current has been alleged. The use of a high tension discharge, and of injected ozone, for the purpose of sterilizing, have often been suggested, and the latter method has been commercially applied. Similar treatment has been applied to sewage, generally with the addition of brine, in order to develop hypochlorites. Foelsing has also devised electrolytic methods for the clarification of log-wood extracts and tanning solutions. Too often, however, the suggested methods conform to no known scientific principles.

### Purifying Liquids, Alcoholic.

The current has been applied in almost every conceivable manner to the treatment of alcoholic liquids, the alleged effect being sometimes to oxidize the aldehydes, sometimes to reduce them, often to sterilize, and occasionally to promote fermentation, and always to improve the flavor and "age" the liquor.

### Purifying Liquids, Sugar Solutions.

The success of the Schollmeyer method of treating sugar solutions depends on the use of soluble electrodes of zinc. The electrolytic portion of this method is essentially the same as the application of zinc electrodes for the purification of water, but the soluble electrodes have the further function of preventing inversion of the sucrose, and the neutralization of the organic acids greatly lessens the quantity of lime required. A considerable increase in purity follows the precipitation of the nitrogenous matter. A distinct method, of which many modifications have been suggested, depends upon the employment of a compartmental cell, the sugar solution being separated from a compartment containing water by diaphragms of parchment paper, and the electrodes being so disposed in the liquids as to remove the acid or basic radicals of the contained salts, thereby correspondingly increasing the purity of the solution and eliminating some of its more melassigenic impurities.

### Solid Electrolytes.

The suggested uses of pyroelectrolytes relate as yet solely to their heating effect, and this class consists therefore of cross references from electric furnaces.

### Solvents Other Than Water.

The literature relating to conductivity of non-aqueous solutions is abundant, but the technical applications are few, although certain plating methods utilize glycerine as a solvent, and Kahlenberg has obtained metallic lithium from solutions in pyridin.

### Synthesis, Oxids of Nitrogen.

This class is substantially limited to gas reactions, accomplished usually through the agency of the high tension discharge or the arc between carbon or metal terminals, and includes the elaborate researches of Berthelot, the work of Slosse and others, upon the synthesis of sugars, the production of oxids of chlorin and alleged allotropic modifications of chlorin, the synthesis of acetylene, ammonia, cyanogen, hydrocyanic acid, chlorids of carbon, etc. The synthetic reduction of oxids of nitrogen has assumed such importance as to entitle it to separate classification.

### Tanning.

This class includes the electrolytic rapid tanning methods, and also such chrome tanning processes as utilize the reducing effect of electrolytic hydrogen.

### Vacuum Deposits.

These serve, as a rule, as a basis for further deposition upon non-conductive bodies, and have been referred to under the

title "Cathodes, Metallizing." The question has, however, been widely studied aside from this application.

Consideration of the foregoing outline will show that the residual class entitled "General Art" is substantially limited to investigations of a general character, the results of which are applicable to the entire field of electrochemistry; and to those investigations which appertain neither to solutions, to molten electrolytes, nor to furnace methods, that is to say, such gas reactions as do not involve synthetic effects and are therefore excluded from the class of "Syntnesis."

## STANDARD ELECTRODES.

By WOOLSEY MCA. JOHNSON.

In the two preceding articles on electrode potentials, I attempted to explain, first, what electrode potential is, and next, how electrode potential can be measured. This third article will discuss the various standard electrodes from several points of view.

It is an axiom that in the finite world of physics to measure any quantity, we must have both a unit and a zero point. Now, both the unit and the zero point can be varied to suit the particular case in hand, or can be fixed definitely with the idea of a maximum benefit to the measurers.

The unit of potential, the volt, is well fixed as a derivative $\frac{1.000}{1.433}$ from the C. G. S. system, and is legally defined as $\frac{1.000}{1.433}$ part of the e. m. f. of the special electrochemical system, the Clark cell

The zero point, however, is not so well defined and is the subject of much learned discussion, in regard to the point of "absolute potential."

Just as we can take any arbitrary standard in measuring level (e. g. the mean level of the ocean), and in measuring temperature (e. g. the melting point of ice in the Celsius or centigrade scale, and the temperature more or less inconstant made by mixing definite amounts of ice and sodium chloride in the Fahrenheit scale), so we can take any arbitrary standard in the measuring of electrode potential. It is entirely immaterial, as far as we are concerned, whether we place the e. m. f. of the "calomel electrode" at — 0.560, — 0.277 or even — 1.560, so long as we make the proper correction when we change from one scale to another. The question is largely one of convenience to the present and future generation of electrochemists.

There is no great significance in the theoretical deduction that the so-called "drop mercury-electrode" possesses the same potential as its solution, for, whenever two solutions are in contact there also is found the seat of e. m. f.

In the case of measuring temperature, the case is quite different, as we have good theoretical grounds for believing from the coefficient of temperature-change in the volume of gases, in the electrical resistance of metals, and in the heat reactions of chemical change that at — 273° C or o° on absolute scale, the molecules are motionless, and therefore possess no kinetic energy.

Theoretically it would be desirable to have an exactly analogous zero point for electrolytic work, *par example*, an electrode that possessed no free energy as regards to its electrolyte. Then the passage of a current in either direction would neither absorb or evolve energy. But, as remarked in the case of the mercury drop-electrode, this would be true for only one electrolyte.

On the other hand, there are several advantages of the so-called hydrogen electrode for convenience in expressing electrochemical data. The hydrogen electrode marks the dividing line between two classes of metals, as follows:

(1) Those that displace hydrogen out of strong mineral acids, as Zn, Fe, Cd, Ni.

(2) Those which do not displace hydrogen out of strong mineral acids, as Cu, Ag, Hg, Au.

It equally well defines the above two classes, by the point of electro-deposition out of acid solution.

Also, when we measure the Casparian overvoltage, we have a line on the reducing power of the cathodic hydrogen, dependent on the nature of the cathode and catholyte. In organic reductions this is of vital importance

On the other hand, it is true that the hydrogen electrode represents considerable work to produce, and only reaches slowly its true value in alkaline solutions.

From an experimental point of view the hydrogen electrode has but one great advantage over the calomel electrode—it introduces no foreign ions into the solution. Consequently, no chain of indifferent electrolytes is needed between it and the electrode to be tested.

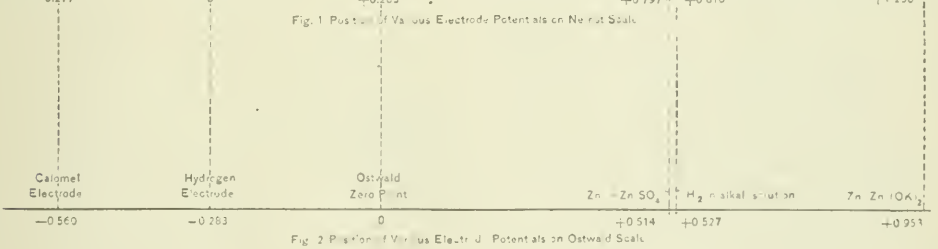



Fig. 1 Positions of Various Electrode Potentials on Nernst Scale.

Fig. 2 Positions of Various Electrode Potentials on Ostwald Scale.

The so-called "calomel electrode" was fixed at — 0.560 volts some years ago by Prof. Ostwald, of Leipzig. When once made (and it is an easy matter to make one, when the pure materials are at hand), it stays at the true voltage and does not polarize unless many coulombs are taken from it. The current which will polarize seriously the electrode depends on the area of the electrode As the electrode can be easily made large in area the polarizing current will be correspondingly large. The hydrogen electrode will polarize easily and will recover also with time.

A marked point of superiority of the "calomel electrode" over the hydrogen electrode lies in the difficulty of passing the hydrogen continuously through the purifying solution and thence through the electrode. A small trace of oxygen will combine with the "nascent," or, to be more correct, the "electronic" hydrogen of the hydrogen-platinum alloy of the electrode This will diminish the electrolytic solution pressure of the hydrogen electrode, so that its potential is not a constant, and it is useless as a standard

In the case of almost any metallic cathodic-deposition, or of an electrodissolution of a metallic anode, a test electrode of the same metal and the same electrolyte as is used in the electrolytic bath is ideal For theoretical deductions its poten-

tial can be reduced to that of hydrogen electrode or Ostwald zero by a simple arithmetical calculation. And the cathode potential which is a measure of the purity of the metal deposited at the cathode can be always measured against the test electrode. Any change from "the initially good conditions" can be read in change from original reading. Concentration changes in the immediate neighborhood of the cathode will be shown by changes in electrode potential of the cathode.

At the anode, similar effects can be studied. If we measure the anode potential, we have a measure of the force which is pulling the different metals into solution. By weighing and analyzing the different slimes, the "sliming effect of the different anode potentials can be determined." In such work, it is essential to have a diaphragm between anolyte and catholyte. The slimes conduct the current fairly well and are very fine. In this condition, they are pulled to the cathode by electrostatic attraction, if by diffusion they come under its influence. Not only do they thus make "warty" deposits, but they contaminate the cathode. If the anode contains precious metals such an action causes a loss in values. This action has, unfortunately, never been studied thoroughly. It is without doubt of utmost importance for practical work. A sharp distinction must always be drawn between "true" electrolytic dissolution and this action, which can be termed "apparent" or false "electro-dissolution."

FIG. 3.

No better electrode than this metal-metallic-salt combination can be well imagined, for it does not polarize even at 0.1 ampere per square decimeter, is easy to make and keep constant. Measuring, as it does, the change from "initially good conditions," it can be taken as a special arbitrary zero of electrode potential in each case. For the electrolysis of copper, nickel, iron, cadmium, zinc, lead, silver, etc., a test electrode of this type is most useful.

In storage battery work, the use of the cadmium electrode is almost too well known to require mention. Its aid to the engineer in detecting deteriorated plates is invaluable. This was mentioned in the paper in the July number. For further details the reader is referred to Lamar Lyndon's book, "Storage Battery Engineering." The electrode is not accurate, for the reason that its potential depends on the equilibrium of the equation,

$$Cd + H_2^{\cdot\cdot} + SO_4^{''} = Cd^{\cdot\cdot} + SO_4^{''} + H_2$$

as determined by the electrostatic action of the "double layer." This will vary with the density of the acid and nature of the electrode. If the cadmium electrode is dipped in the bottom of the cell at the end of charge, when the acid is concentrated in the bottom, its potential is increased toward the electro-positive side of the series. This, of course, is due to the fact that the acid is more dense in the lower part of cell, which can be likewise proved by chemical analysis. It has been a remarkable fact that storage battery engineers gave up after a few unsuccessful trials the idea of a "top-bottom" circulation. Anyone who has seen the buckling and corrosion on lower plates of the "double-plated" cells, must realize that a more uniform current density would prolong the useful life and increase the capacity of the plates. A uniform current density would be rendered by proper circulation.

For alkaline solutions the zinc-zincate electrode can be recommended. The electrolyte should be a solution of the same alkalinity as used in the electrolytic vat, saturated with zinc. The saturation can be done chemically by shaking up freshly prepared $Zn(OH)_2$ with the electrolyte or electrochemically by putting the zinc as anode in the KOH solution with a porous diaphragm. The e. m. f. of this system against the hydrogen electrode was found to vary slightly with the concentration, and was about 0.405 volts. Wilsmore found the value 1.236 volts against the hydrogen electrode in *acid* solution.

As an example of conversion from one scale to another this is excellent, and we will calculate the various positions graphically in Fig. 1.

The upper scale is based on the normal acid hydrogen electrode, which possesses a potential of + 0.277 volts, against the normal calomel electrode. Accordingly the acid hydrogen electrode is — 0.283 volts, against the Ostwald standard, which places the calomel electrode at — 0.560 volts. On the Nernst zero point scale, based on the hydrogen normal electrode, the system Zn — $N.ZnSO_4$ is about + 0.797 volts. The hydrogen electrode in alkaline solution is + 0.810 volts on the Nernst scale, and the system Zn, $Zn(OH)_2$ is + 1.236 volts on the same scale. The difference 0.426 volts is the difference of potential between zinc and hydrogen in alkaline solution. The value, found by me as about 0.405 volts, is smaller by 0.21 volts. This is due to the fact that I saturated the KOH electrolytically with Zn (which naturally decreased the free energy of the system and thereby diminished the e. m. f.).

In Fig. 2 we see the same voltages transferred to the Ostwald scale.

As both the "calomel" and "hydrogen" electrode are used in experimental work, both will be described in some detail.

The hydrogen electrode consists of a glass tube connected with the electrode to be tested by means of a siphon of rubber or glass tubing, and in which glass tube dips a sheet of platinized platinum; through the glass tube B is passed a stream of hydrogen, by means of the pointed tube. The whole apparatus is best made by a glass blower. The electrode is thus an electrode of platinum-hydrogen alloy. To secure proper dissolving of the hydrogen in the platinum, the platinum must be in the spongy condition.

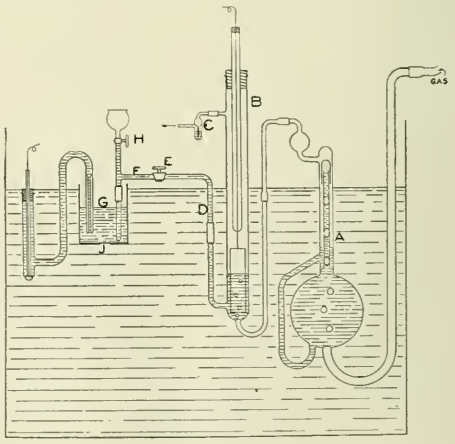



FIG. 4.—HYDROGEN ELECTRODE.

The sheet platinum, 0.1 mm. thick, 4 cms. wide and 5 cms. long, is welded to a platinum wire 0.1 mm. in diameter before a blow-pipe on a small anvil. For details for welding platinum the reader is referred to Ostwald's "Physico-Chemical Measurements." This platinum wire is about 6 cms. long, and is soldered autogenously to a No. 14 copper wire. This soldering is done before a blow-pipe, and is rather hard to perform for the temperature at which the copper alloys with the platinum is above the melting point of the copper. One is very apt to melt the copper wire off. However, by blowing on the flame, just at the moment the alloying takes place, the juncture is cooled and the joint is made. The platinum wire is sealed in a glass tube 15 cms. long, with some glass that sticks to platinum. The top of the tube is sealed with sealing wax. The whole can be seen in Fig. 3.

The platinum sheet is next cleaned from organic matter by heating to white heat in the flame of the blow-pipe, then cleaned by boiling in 5 per cent KOH for thirty minutes, then thirty minutes in 20 per cent $HNO_3$, and finally boiled for one hour in distilled water. One can be reasonably sure then that the surface is clean.

The platinizing solution should contain about 30 grams Pt. to the liter in the form of acid platinous chloride, the current density should be about 20 amperes per square foot. Dilute solutions make a spongy deposit, but too spongy deposits are not adherent. The addition to the solution just before plating of 0.01 per cent lead acetate helps matters greatly.

Two electrodes are placed in a small beaker filled with this solution as anode and cathode. A reversing switch is included in the circuit. The plating operating is continued for thirty minutes, reversing the current every five minutes. At the end of the electrolysis both the electrodes are platinized, for the operation is not reversible and more platinum is deposited when the electrode is cathode than is dissolved when the electrode is anode. The platinized electrodes should be washed in hot water and then in hot 20-per-cent $HNO_3$ to dissolve the lead. The electrode thus prepared is set in tube B, Fig. 4, and sealed by means of a parafined cork, bored to receive the small glass tube. The electrode is sealed with sealing wax to preclude any leaking in of air.

Hydrogen made from zinc and sulphuric acid is passed through the electrolyte, as can be seen in Fig. 4. The hydrogen should be washed with alkaline potassium permanganate solution in a Richardson gas-washing-apparatus, then with the same solution as the electrolyte is a second Richardson gas-washing-apparatus A. C is a small water seal.

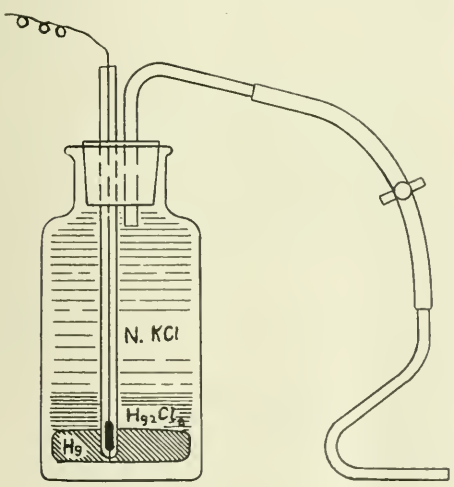



FIG. 5.—OSTWALD CALOMEL ELECTRODE.

The electrode proper should only dip one-third of its height in the electrolyte. The reason for this is that the hydrogen diffuses into the "sponge" above the surface of the liquid much faster than below. The hydrogen occluded above soaks down through the sponge, just as water will soak slowly through a marsh. Finally we reach a point of equilibrium and the hydrogen is at equal pressure all through the electrode.

The "calomel" electrode is easier to prepare and keep constant than the hydrogen electrode. It consists of a glass bottle of 150 cms. capacity. At the bottom of the bottle is a layer of mercury 1 cm. high. The mercury should be chemically pure and should leave no smudge on a porcelain dish when allowed to stand for twenty-four hours exposed to the air. This is a very delicate chemical test. The commercial mercury can be purified by shaking with dilute $HNO_3$. The mercury is covered with a 2-cm. layer of pure $Hg_2Cl_2$ calomel—whence the name "calomel-electrode."

Above the calomel completely filling the bottle is the electrolyte, a normal solution of KCl—potassium chloride. The mouth of the bottle is closed with a tightly-fitting rubber stopper through holes in which are passed two glass tubes. One glass tube makes connection with the mercury by means of a sealed platinum wire. The other glass tube makes electrolytic connection by means of a rubber tube to the electrolyte, in which the electrode to be tested dips. Thus, we have a closed electrochemical system, one of whose members we know.

As can be readily imagined, the electrolyte in the vat must not react chemically with the KCl. If it does, a third electrolyte, indifferent to both, must be included in the circuit.

The metal-metallic salt electrode can be made in similar bottle to that used in the "calomel" electrode. Instead of a layer of mercury, a spiral wire can be used. Of course there is no depolarizer needed in this case.

The different conclusions about the various standard electrodes can be summed up as follows:

The advantages of the normal hydrogen-electrode in fixing a line dividing the two classes of metal—base and noble—by their electrolytic pressure, and giving a measure of the chemical potenial of the cathode and catholyte and anode and anolyte, are so great that its use as a zero point in expressing electrochemical data saves much mental labor.

As a work standard, the hydrogen electrodes present too great technical disadvantages.

For most research work the "calomel" electrode is admirable in its constancy and ease of manufacture. Its results can always be reduced to the normal hydrogen standard.

For most practical work with a soluble metallic anode and metallic deposition, a standard electrode of same metal and same electrolyte as is used in the large vat is advantageous for two reasons:

(1) It is easy to make and set up.

(2) It records differences between original electrochemical system, and that set up by the changes on course of electrolysis.

In all the above cases it must be remembered that the measuring instrument or apparatus must be designed with regard to the fact that there is a resistance of several thousands of ohms between the vat and the test electrode due to the small cross-section of the tube of liquid connecting the two.

Often in practical work a metallic test electrode can be dipped directly in the electrolyte, provided there is no chemical action between the two. Then a voltmeter can be employed.

In further articles I will treat the question of electrode potential from the standpoint of the dissociation theory and thermodynamics.

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American Electrochemical Society.—At the meeting of the Board of Directors, held in Philadelphia on October 10, the following gentlemen were elected members of the Society: Paul J. Kruesi, Chattanooga, Tenn.; Sherard Cowper-Coles, London, England; W. A. Johnston, Princes Bay, N. Y.; I. A H. Glenck, Riga, Russia; R. N. Kofoid, Niagara Falls, N. Y.; J F. Merrill, Salt Lake City, Utah; C. E. Finney, New York; R. H. Aiken, Sault Ste. Marie, Mich.; Joseph Bijur, New York; H T. Darlington, Philadelphia, Pa.

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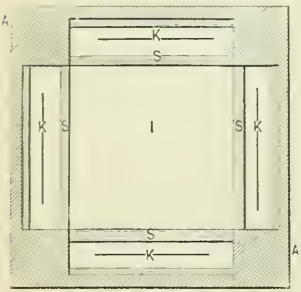
Erratum.—The biographical sketch of Mr. Charles S Bradley, published in our September issue, contains an error in the date of one of the patents discussed. The second patent granted to Mr. Bradley for an improvement of his bromide battery is No. 309,448, of August 20, 1884 (instead of February 24, 1885) His first patent for this battery is No 312,802, of February 24, 1885.

## HISTORICAL SKETCH OF THE DEVELOPMENT IN THE PRODUCTION OF COPPER, NICKEL AND ZINC FROM CHLORIDE SOLUTIONS.

By William Koehler.

The idea tending toward the utilization of chloride solutions in the electrochemical production of metals seems to have had its inception with Body, who, in January, 1886, applied for the first patent in this direction. The purely metallurgical chemical engineering art had, up to this date, long known the utilization of iron salts, especially the oxidation, reduction and solvent powers of its respective sulphates and chlorides. Body's process and apparatus may be looked upon as the forerunner of the Siemens-Halske and the Hoepfner processes. Body's process did not limit itself to copper, but embraces all metals capable of solution and subsequent precipitation. In carrying out the process Body employed a vessel built up of concrete or Portland cement, covered with a water-proof paint or coating. The adjoining diagram gives an idea of Body's electrolytic bath.

A is a cement or concrete vessel, S are partition walls extending half-way down to the carbon bottom C. F are diaphragms of felt cloth, enclosing the space between S and C, K the cathodes, R a stirrer, O the inlet for electrolyte, O' the outlet for electrolyte.



HORIZONTAL SECTION

FIG. 1a.—BODY CELL.

The electrolyte used consisted of a ferric salt in conjunction with sodium chloride. The ore from which the metal was to be extracted and precipitated was previously saturated with the electrolyte and thoroughly worked over, and was then placed in compartment I, and during the time of electrolysis kept in motion by means of the mechanical agitator R. The electrolyte entered the bath through the opening O in the central compartment, took the course as indicated by the arrows over the partition walls through the cathode compartments past the cathodes K, and left the bath through the opening O' at the bottom of the cathode compartments. During the passage of the electrolyte in the described course, the following reactions take place:

1st. The metals contained in the ore are brought into solution through the reduction of ferric salts to ferrous salts.

2nd. The dissolved metal is plated out upon the cathodes.

3rd. The chlorine generated at the anode C oxidizes the ferrous salts back to ferric salts. The chlorine evolved but not used in this oxidation acts directly in the nascent state upon the ore or metal which is in direct contact with the anode plate.

At about this time the late Dr. Hoepfner, who had been in the employ of the Siemens & Halske Co., of Berlin, conceived the idea of using cupric chloride instead of the ferric chloride employed by Body and ferric sulphate used in the Siemens & Halske process as lixiviant electrolyte. Hoepfner's original process was patented in 1888. The process as described by Dr. Hoepfner, according to a report made to the Oberschlesische Bezirksverein für Angewandte Chemie, is as follows: Electrolytic baths are employed which are separated through suitable diaphragms into anode and cathode compartments, and allow an independent circulation from anode to anode, and cathode to cathode compartments in any desirable series or number. In the anode compartments are placed insoluble anodes generally formed from gas retort carbon, in the cathode compartments sheets of pure copper. A solution of perfectly reduced cuprous chloride in a salt or calcium chloride solution passes the anodes, and a similar one passes the cathodes.

At the cathodes metallic copper is plated out at a rate of 2.36 grams per ampere hour, exactly double the quantity as precipitated from an oxide salt of copper, such as copper sulphate, from which 1.18 grams are deposited per ampere-hour. At the anode, in case no cuprous chloride is present, chlorine will be liberated and a potential difference of 1.8 volts will be necessary to effect the dissociation, but as cuprous chloride is always present at the anode, the chlorine ions react with cuprous chloride and the formation of cupric chloride results. This oxidation, corresponding to an evolution of energy, produces an e. m. f. which amounts to about one volt, and in the same direction as the working current, so that it aids the electrolytic deposition and reduces the power necessary to plate out the copper. The electrolysis practically proceeds with a potential difference of 0.8 volts, at the terminals of the cell. The cathode electrolyte passing the cathodes has its copper contents precipitated and eventually becomes free from copper. It is then withdrawn from the series of baths to be later taken up in the cycle for the purpose of restoring the original solution volume. The anode solution retains its original contents, but at the end of the operation the copper no longer exists as cuprous chloride, but is completely oxidized to the cupric condition and flows from the baths as cupric chloride. The anode solution is now in condition to extract more metal, and is therefore treated with finely ground ores or matte, and the copper, silver and other metallic constituents are extracted therefrom. For this purpose special revolving leaching drums are employed which have a capacity approximating to cubic meters, and afford excellent stirring and agitating facilities. With sulphide ores the following reactions take place:

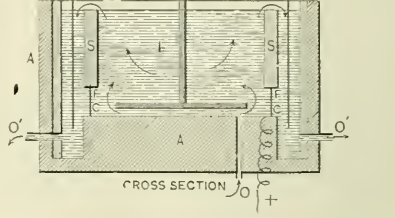


FIG. 1b.—BODY CELL.

$$CuS + CuCl_2 = Cu_2Cl_2 + S$$

$$Ag_2S + 2CuCl_2 = Cu_2Cl_2 + 2AgCl + S$$

Accordingly, cupric chloride, through treatment with copper sulphide, is reduced to cuprous chloride and sulphur separates. Silver sulphide is converted into silver chloride, and, being soluble in the chloride solution, is taken up. The regenerated cuprous chloride which has been clarified, and, as later described, freed from silver, arsenic, bismuth and all such impurities which would contaminate the copper, after being mixed with the cathode solution from above, is then allowed to circulate in two separate portions, one through the anode and the other through the cathode compartments. At the anodes cupric chloride is regenerated, while at the cathodes copper is deposited.

The purifying of the solution is best accomplished through direct chemical means, employing copper oxide, caustic lime or alkali, whereby arsenic, antimony and bismuth, which have a decided deleterious effect upon the deposited copper, are removed. Silver is either chemically removed by means of copper shot, potassium iodide, etc., or electrolytically before the copper. By means of caustic lime the iron which had been

taken up is also removed. If this was not removed, the iron contents of the electrolyte, and incidentally of the lixiviant, would gradually increase to such an extent that the solvent of the original lixiviant would be reduced to about one-quarter of its value. The quantity of copper precipitated by a mechanical horse-power (taking 730 volt-amperes for twenty-four hours at a potential difference of 0.8 volts, including 10 per cent loss of current) is approximately 43 kg. (theoretically 46.4 kg.) In view of the fact that in larger power plants only 22 kg. of coal are required per horse-power-day, we find that with an economical management 1 kg. of coal suffices to produce about 2 kg. of electrolytic copper. Taking into account 1 kg. coal addition for ore grinding, leaching, pumping, etc., we have the production of 1 kg. of copper to the expenditure of 1 kg. coal. This makes it possible to extract copper even in districts where fuel is scarce. The following economical advantages of the described process were claimed by Dr. Hoepfner:

1. Greater capable effect of the electric current, 2.37 grams per ampere-hour of copper being precipitated from cuprous chloride, as against 1.18 grams per ampere-hour from a copper sulphate solution. On account of this feature, the installation cost is reduced one-half.

Second. The greater capability of chloride solutions, compared with sulphate solutions, of dissolving all the valuable metallic constituents contained in the raw ore.

Third. The high concentration of the solution, chloride solutions being capable of taking up 150 grams of copper per liter. In consequence thereof the leaching department requires less space and mechanical energy as against a sulphate leaching plant. Dr. Hoepfner concludes this report with the words: "Notwithstanding that I may say the above-described process has been practically proven, it is still possible that the same may undergo many changes and improvements by which the cost of producing copper will still further be reduced."

The hopes as entertained by Dr. Hoepfner at that time did not mature, although the process was exploited at the Schwarzenberg Refinery in the Saechsische Erzgebirge and at Weidenau-Siegen in Westialen. The obstacles preventing the successful operation of the process, and which have since been overcome or brought to a state of commercial applicability, may be summed up as follows: First, in order to effect a complete extraction, a fine grinding of the ore or furnace product is necessary; the cost of such grinding is in many cases prohibitive. Second, as it is necessary in some instances to apply external heat in the leaching process, a solution of the iron and other undesirable compounds is unavoidable; this fouls the solution and also lessens the solvent action of cupric chloride. Third, filtering and washing residues is a difficult problem. Fourth, suitable anode and diaphragm materials.

At the present time the anode question may be considered as solved. The Acheson Graphite Co., of Niagara Falls, N. Y., are producing a graphite carbon which withstands the action of nascent chlorine as also copper chloride in an exceedingly satisfactory manner. The diaphragm problem seems to have been solved to a certain extent by the interesting researches of Cohen. This chemist noticed in the electrolysis of a cuprous chloride solution at a low current density that the cupric chloride produced at the anode formed a specifically heavier solution than the cuprous chloride electrolyte. On account of its greater specific weight, cupric chloride sinks to the bottom of the vats and forms a separate and distinct layer which constantly increases in volume, displacing mechanically the cuprous chloride electrolyte. By means of the apparatus as shown in Fig. 2 the deposition of copper was effected without the use of a diaphragm, and at a potential difference of less than one-half volt. This gives an output of approximately 74 kg. (163 pounds) per electrical horse-power day, allowing 10 per cent loss in current

During 1892 the Hoepfner process was further exploited at the electrolytic bismuth refinery of Mr. George Throm, Giessen, Germany, upon copper and nickel bearing materials, the object being to devise a method for the economic separation of copper from nickel with the ultimate end of producing pure copper and nickel from mixed ores or furnace products.

At this same time the production of zinc, together with chlorine gas and bleach was being thoroughly tested along experimental lines by Dr. George Wannschaff at the Hoffmann Co., Eiserfeld-Siegen, under the jurisdiction of Mr. G. Meune. The process as applied to copper and nickel-bearing material is similar to the extraction of copper alone, and may be described as follows: Copper-nickel ores, matte or furnace products after being ground to 60 mesh were subjected to a leaching process with a solution of cupric chloride containing from 50 to 75 grams of copper per liter. This leaching was effected in revolving drums of about 5 cubic meters capacity. The solution, after being thoroughly reduced, was allowed to cool and clarify, and after removing the small amount of

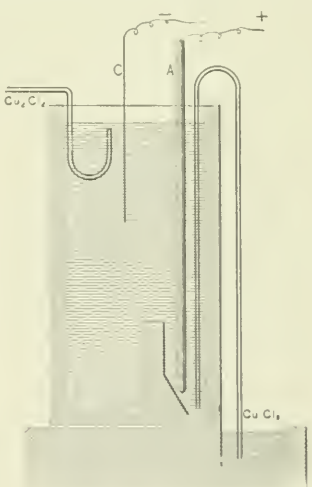



FIG. 2. APPARATUS OF COHEN

silver which it contained through precipitation with metallic copper was subjected to electrolysis.

The reactions taking place during leaching are:

(1) $CuS + CuCl_2 = Cu_2Cl_2 + S$

(2) $NiS + 2CuCl_2 = Cu_2Cl_2 + NiCl_2 + S$

(3) $Ag_2S + 2CuCl_2 = 2AgCl + Cu_2Cl_2 + S$

Iron, gold, lead, cobalt, zinc, etc., also go into solution if present in the raw material. The electrolyte consists, after purification, of cuprous chloride and nickel chloride dissolved in a solution of salt or calcium chloride. This electrolyte was then conveyed to double compartment baths in two separate channels, one going to the anodes and the other going to the cathodes. The cathode solution upon flowing past sufficient cathodes lost its copper, while the anode solution, through the action of the chlorine ions, was oxidized back to cupric chloride. The anode solution coming from the baths was again utilized to dissolve more metal from the mattes or ores.

The cathode solution after being deprived of its copper contents, consisted of a nickel chloride solution, which, after thorough purification, was again subjected to electrolysis at a proper voltage in baths having closed anode cells containing carbon anodes. The cathodes consisted of revolving sheet iron discs, upon which the nickel was deposited. The chlorine gas liberated was returned to the leaching department to effect the further decomposition of the copper nickel-bearing raw

material. The reactions taking place during electrolysis are summed up as follows:

(4) $2Cu_2Cl_2 + 2NiCl_2 + \text{current} = 2Cu + NiCl_2$ (at cathode) $+ NiCl_2 + Cu_2Cl_2 + Cl_2$ (at anode)

Secondary reaction at anode $Cu_2Cl_2 + NiCl_2 + Cl_2 = 2CuCl_2 + NiCl_2$

(5) $NiCl_2 + \text{current} = Ni + Cl_2$

*(To be concluded.)*

## INTERNATIONAL CONGRESS FOR APPLIED CHEMISTRY.

Report of the Proceedings of Section X.
(Electrochemistry and Physical Chemistry.)
By H. Danneel, Ph. D., and J. K. Clement.
(Continued from page 512.)

Meeting on June 4, Afternoon.

Tests and Analysis of Carbides.

In a paper on this subject Mr. Gall recommended the acceptance of the proposals of the German Acetylene Society. He then spoke about the determination of sulphur and phosphorous in carbides. On dissolving carbide in a large quantity of water all the sulphur present remains in the milk of lime, and it can be determined as $BaSO_4$. Phosphorous, on the other hand, passes over quantitatively into the gas. It is therefore necessary to fuse the carbide with $NaNO_3$. The phosphorous in the residue can then be determined with molybdenum. Speaker gave the results of a series of analyses.

Meeting on June 5, Afternoon.

Electrochemical Units of Measurement.

In a paper on this subject Prof. W. Nernst gave an historical review of the origin of the committee for the establishment of electrochemical units, also the reasons of the committee for establishing for the present only a small number of symbols and for adopting as far as possible the hitherto customary ones. The suggestions of the committee are contained in the following table:

Variables.

p, P Ordinary and osmotic pressure.
v Volume.
T Absolute temperature.
Θ Celsiustemperature.
t Time.
δ Density.
△ Vapor-density referred to air.
$\pi_k$, $v_k$, $\vartheta_k$ Critical quantities (pressure, volume, temperature).
$\pi$, $\varphi$, $\upsilon$ Reduced quantities (pressure, volume, temperature).
Q Quantity of heat.
U Internal energy.
a Atomic weight (O = 16).
M Molecular weight ($O_2$ = 32).
c Specific heat.
$c_p$, $c_v$ Specific heat at constant pressure or volume.
$C_p = c_p M$, $C_v = c_v M$ Molecular heat at constant pressure or volume.
N Index of refraction.
κ Conductance in reciprocal ohms per centimeter-cube.
η Concentration (gm.-equivalent per ccm).
$\Lambda = \frac{\kappa}{\eta}$ Equivalent conductivity.
$\Lambda_\infty$ Equivalent conductivity at infinite dilution.
ν Degree of Dissociation.
K Equilibrium-constant of the law of chemical mass-action.
E Potential-difference.
W Resistance.
I Current-strength.
ε Electrode potential, decomposition-potential.
$\varepsilon_h$ Potential with reference to a normal hydrogen-electrode.
$\varepsilon_c$ Potential with reference to a normal calomel electrode.

Constants.

R Gas-constant per mol.
A Mechanical Equivalent of Heat $41.98 \times 10^6$ erg per gm. cal. at 15°.
F Valence-charge (96,540 coulombs per gm. equivalent).

Abbreviations in Text.

2n. $H_2SO_4$, etc., for double equivalent sulphuric acid, etc.; $H^{\cdot}$, $Cl'$, $Ba^{\cdot\cdot}$, etc., for singly charged positive H-ion, singly charged negative Cl-ion, doubly charged positive Ba-ion, etc.

In the discussion which followed Prof. Noyes, of Boston, raised the following objections to the suggestions of the committee. First, the incompleteness of the table, since some of the most fundamental quantities used in chemistry are not considered, e. g. mass, energy, work, entropy, force, velocity, acceleration, distance, height, surface, radius, number of mols, reaction-velocity, and solubility. If the system of the committee should be now adopted, it will be more difficult to introduce later a complete and rational system of notation. The whole matter must be taken into consideration at one time; to adopt a notation for a few quantities, and to leave many others, some of which are still more important, to further agreement or arbitrary selection, is as unsatisfactory as it would have been for chemists to adopt first symbols for the metallic elements (for example, N for sodium [natrium], C for calcium) while leaving the non-metallic elements temporarily unprovided for (thus precluding the use of N for nitrogen, and C for carbon). His second objection was that the proposed notations are not rational or systematic, not being based on any general principles. Noyes proposes to designate all electrical quantities by a certain style of type, e. g. small capitals, optical quantities by a certain other style, such as Greek letters, and specific properties by underlining the letter representing the general properties, for example, V = volume in general, $\underline{V}$ = specific volume. His third objection was that the matter ought to be considered by an international committee before accepting it, in order that full justice may be done to the usages of different countries. Noyes suggested that the Section X. recommend to the Congress the appointment of such a committee to consist of five members. To show how the matter could be arranged, Noyes presented the table which he used in his book.

Dr. Nernst replied that with such a revolutionary procedure as Noyes suggested it would be impossible to bring the suggestions into general use, as the force of habit is too great to be overcome by the best and most complete system. Nernst agreed to the appointment of an international committee, but in his opinion this did not prevent the acceptance of the report of the commission.

The motion of the committee to recommend to the Congress the acceptance of the above system of notation was then unanimously carried. Noyes' amendment was rejected, although Nernst and the great majority of the other German professors and instructors present were in favor of it. In the opinion of the reporters (Danneel and Clement), the question to be voted upon was not sufficiently clearly stated. Moreover, the attitude of Section X. in rejecting the amendment was afterwards redeemed by the entire Congress, which complied with Noyes' suggestion and appointed a committee.

The report of the committee appointed by the Congress of 1900 to establish uniform symbols for the fundamental electrochemical quantities was then presented by Prof. Marie of Paris, who gave a review of the various suggestions which had been submitted to the committee and joined in the suggestions of Nernst.

The remaining papers of Session IV. were physico-chemical and not electrochemical. Prof. Schenck, of Marburg, spoke

on the dissociation of carbon monoxide. He had measured the equilibrium and the order of the reaction $2CO = C + CO_2$, in the presence of various metals. Nickel and cobalt act as catalytic agents and accelerate the reaction. Iron participates in the reaction according to the equation $2Fe + 3CO_2 = Fe_2O_3 + 3CO$, as long as the carbon dioxide pressure remains above a certain value. Below this pressure iron acts only as a catalytic agent. The author makes from his experiments certain deductions concerning the order of the reaction, at low temperatures (310°) the reaction is monomolecular, at higher temperatures (510°) bi-molecular.

In the discussion Bodenstein called attention to the fact that one must be cautious in drawing conclusions concerning the order of such a reaction because, in the first place, on account of too little diffusion very often a different equilibrium sets in near the catalytic agent than the one measured, and secondly there is danger that, on account of the great "heat effect" of the reaction, local rises of temperature may occur so that the temperature is not uniform.

### Variation of Electric Resistance Under the Influence of Light.

A paper on this subject was read by L. Ancel. Due to the great change of resistance which it undergoes under the influence of light, selenium has become very important for tele photography. It is very expensive and is injured by the action of extra currents. Soot, tellurium and thin leaves of various metals undergo a similar change of resistance under the influence of light, but are not sensitive enough. Selenium covered with soot is more sensitive than selenium alone, and is free from the defects which are peculiar to the latter.

*(To be concluded.)*

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

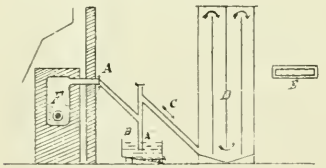
*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

By Carl Hering.

*Industrial Electrolysis of Water.*—The production of hydrogen and oxygen, though one of the oldest electrochemical experiments, and proposed in a large number of patents, has been carried out industrially only to a limited extent. There was considerable difficulty in developing the laboratory apparatus so that it would operate successfully in practice, one of the hardest conditions to meet being the necessity of absolute safety of operation, and this required the exclusion of every possibility of the formation of an explosive gas mixture. Another difficult matter was the necessity of providing a material for the electrodes, which is not at all or only slightly attacked by the electrolyte, and the necessity of constructing apparatus with a small internal resistance. In the September number of the *Electrochemische Zeitschrift*, Schoop discusses the various processes which have been applied on an industrial scale, and gives data on the employment of hydrogen and oxygen for soldering purposes. The principal processes used in practice are those of Garuti, Schmidt and Schoop. In the first two the electrolyte is an alkali, and in the last an acid. Garuti's process depends on a metallic diaphragm, the lower part of which is perforated, thereby permitting free communication of the liquids in the different compartments of the apparatus, but preventing a mixture of the gases as long as the gas pressure does not go above a certain limit. If this is not carefully regulated, however, the formation of an explosive mixture of gas can easily take place. It is absolutely necessary not to go above 3.4 volts for the pressure of the bath, in order to prevent the metallic diaphragms from becoming bipolar electrodes. The electrodes are of iron, and the anodes are slowly decomposed and have to be renewed every two or three years. The caustic soda solution takes up carbonic acid from the air, which has the effect of decreasing its conductivity. The apparatus of Schmidt looks somewhat like a filter-press, and consists essentially of bipolar, iron electrodes, connected in series. Asbestos cloths are used as insulators and for packing, and also for the separation of the gases. One side of each electrode communicates with a canal, which serves for leading off the hydrogen, while the oxygen passes through a similar canal at the other side of the electrode. The apparatus has to be taken apart and cleaned every six weeks and the asbestos diaphragms have to be renewed from time to time. The apparatus constructed by Schoop is not very clearly described, and is not illustrated. Its chief feature seems to be the use of a tubular form of the electrode, which is enlarged at its lower end to the shape of a bell. The electrode material is of lead in the form of a pipe, surrounded on the outside by insulating material; the tubes are connected in parallel in groups of 2, 4, 6, 8, etc. To increase the surface which receives current, a body of lead of star-shaped cross-section is cast inside of the electrodes. One such tube can carry 25 amperes continuously, and there are then set free 5.22 liters of oxygen and 10.44 liters of hydrogen per hour The voltage for each cell is 3.3 to 3.6. After running some time the cell is similar to a storage cell of small capacity in consequence of the formation of lead peroxide on the positive electrode. With a 110 volt plant there can be 30 of them connected in series. In order to prevent current from the cells being returned to the circuit, a circuit breaker has to be provided. The gases are lead off from the tops of these tubes and the use of diaphragms is thereby entirely done away with, and therefore the formation of explosive mixtures is prevented absolutely. The pressure under which the gases are generated depends upon the length of the lead electrodes, and may be chosen at will within certain limits. In the apparatus as used in practice, the pressure amounts to 60 to 70 cm. head of water, so that no further compression is necessary and the gases can be conducted directly to the oxyhydrogen burners. Extended experiments are said to have demonstrated that 1 e.hp-hour furnishes 48.75 liters of oxygen and 97.5 liters of hydrogen, that is, an expenditure of energy of 6.2 to 6.8 hp-hours has to be made for one cubic meter of detonating gas. The gases are pure, but the oxygen is strongly mixed with ozone, which cannot be prevented with an acid electrolyte The utilization of hydrogen and oxygen forms the subject of the second part of the article, the author enumerating the application for therapeutic purposes, for soldering and welding of various precious and other metals, for aeronautics, for the manufacture of glass, and for illuminating purposes. The application of the gases to soldering and welding is described at some length and is illustrated. For most of the work of this kind, there are required one part of oxygen to four parts of hydrogen, instead of one part of oxygen to two parts of hydrogen, as it is preferable to give the flame reducing properties, and as the oxygen of the air also takes part in the combustion The great advantage of welding with the oxyhydrogen flame consists in the possibility of performing a so-called autogenous weld, that is, without the use of a solder It has been found in practice that for the sake of safety the gases can be mixed only when close to the point where they are burned. It is, however, possible to conduct detonating

gas to the soldering blow-pipe, but there is then always a possibility of the flame striking back. In either case it is of the utmost importance that the velocity with which the gases emerge from the burner should be greater than the velocity with which the flame of the detonating gas propagates itself. Two recent constructions of oxyhydrogen burners are diagramatically illustrated. The soldering of aluminium is said to be easily accomplished with the oxyhydrogen flame, as also the soldering of sheets of iron, copper and brass.

*Extraction of Mercury in the Electric Furnace.*—The advantages of the electric furnace for the extraction of mercury from its ores are briefly set forth by Becker, in an article in *L'Industrie Electrochimique*, September. The ordinary distillation process is first reviewed. If a charge of mercury ore and lime is introduced into the electric furnace and heated, the mercury is entirely distilled off and the discharge of the furnace can be performed without danger. The use of an electric furnace also does away with the cumbersome retorts, and the charging of the furnace can easily be made a continuous operation. The openings by which the electrodes enter into the furnace must not communicate with the atmosphere, but must be provided with cylinders or tubes, in which the electrodes can slide. The system of electrode construction resembles that adopted as early as 1886 by the Cowles Brothers for their aluminium bronze furnaces. The accompany figure gives a schematic representation of an industrial installation.




EXTRACTION OF MERCURY IN THE ELECTRIC FURNACE.

The furnace *F* is placed under a hood, provided with an air-draft. The tube *A*, through which the vapors escape, is formed of two iron tubes placed inside of each other, as indicated at *E*; a current of cold water circulates between them. The mercury which condenses in the tube *A* runs into the vessel *B*, which is filled with water. The uncondensed vapors pass through the tube *C* into the condensation chamber *D*. For each part of mercury in the ore it is necessary to add two parts of lime. When the ore carries pyrite, the quantity of lime must be increased. When the quantity of lime is not high enough, sulphide of mercury distills with the mercury, and when the ore is distilled entirely without lime, the whole of the sulphide of mercury distills off. The power required varies with the contents of mercury in the ore and with the nature of the gangue. This process is stated by the author to be applicable also to poor ores which might be charged directly into the furnace after they are pulverized and the necessary amount of lime added, or which might be subjected to a preceding concentration.

*Electrothermic Processes for the Production of Metallic Powders.*—A brief description of several electric processes for the production of metallic powders is given in *L'Industrie Electrochimique* for September. The Gérard process consists in heating the metals in an electric furnace, which is narrowed down to a small cross-section in the middle. The ends of the electrodes enter the far sides of the furnace at its largest parts. When the furnace is filled with metal the narrow portion of the middle offers the greatest resistance to the path of the current. When the metal, which by preference is melted previously, is introduced into the furnace, it will become hottest in the narrow part of the furnace and will be vaporized there. The metallic vapors are led into a condensation chamber. By blowing air into the furnace at a certain distance above the hearth, the combustion of the metallic vapors can be brought about if desired, and the method is therefore applicable to the production of zinc oxide, tin oxide, etc. Another process, which is briefly described, is applied to the production of oxide of tin. A third process consists in the volatilization of the metal by arcs produced by interrupting a stream of metal which carries the electric current, and introducing a stream of an inert gas or of air if metallic powders or their oxides are required.

*Electric Furnaces.*—Minet gives in the *Electrochemische Zeitschrift* of September, the continuation of his serial on the electric furnace, its genesis, development and forms of application. Several types of Gérard and Street's constructions are illustrated, as also a furnace of Ducrebet of a well-known form.

*Elmore Copper Depositing Process.*—A short illustrated description of the well-known Elmore process for the manufacture of copper tubes is given in the *Electrochem. and Metallurgist*, September. The current density of the cathode is stated to be 600 amp. per sq. meter (56 amp. per sq. foot), and the deposition of a copper tube 4 to 5 mm. thick would therefore take just a week. The three Elmore works in Schladern (Germany), Leeds (England), and Havre (France), are stated to have a total weekly capacity of 396,000 pounds of copper. The English and French works use steam exclusively, while the German works make use of 550 hp from water power and 400 hp from steam. The latter works produce some 2,600,000 pounds of copper per year.

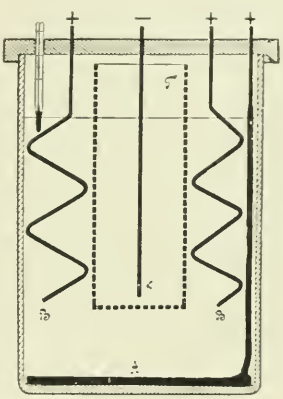
*Polishing and Plating of Metals.*—The continuation of the extracts from a manual under this title by Hawkins, which was referred to previously in the Synopsis, is given in the *American Jeweler* of September. The arrangement of plating shops for room and light, are briefly discussed in the first part. The author next deals with the question of dynamos for electroplating, and discusses the series, shunt and compound machines. The machines are considered in some detail, especially in view of the troubles which constantly occur in plating shops and which are due to the ignorance of electroplaters on the subject of electricity. The capacity of machines for the work they have to do, is referred to, and it is mentioned that owing to the absence of ampere-meters in plating shops, no reliable data exists as to the quantity of current necessary for certain classes of work. The tables of amperes per square foot which exist are wholly misleading. They were made by taking, for convenience, thin sheets of metals and measuring the number of amperes per square foot which could be used for deposition without burning the deposit. He states that they are correct as applied to that sheet, but the mistake was made of supposing that only the surface need be considered. For instance, the tables state that cyanide of copper solutions require six to eight amperes per square foot and acid copper solutions ten to twelve. This, says the author, is true on a sheet of twenty-two gauge, but a plate half an inch thick will take twenty to twenty-seven amperes, and a cast-iron panel three-quarters of an inch thick and four by seven feet in its other dimensions, will require from fifty to sixty amperes per square foot to put the metal on properly in the center without burning at the corners. Twenty amperes per foot is common practice on heavy work where six are indicated in the tables, and nickel-plating direct on sheet zinc will take sixty amperes per foot. A dynamo bought according to the tables will therefore be wholly inadequate for anything but thin metal. The author's explanation as to how the mistake arose is as follows: The limit of quantity of current is at that point at which the metal commences to discolor from the heat evolved when the metal is deposited out of the solution; a thin plate conducts heat slowly beyond a given quantity. On the other hand, a large, heavy piece contains metal enough to conduct the heat away as fast as it is formed, and ten or twelve times as much current may be used profit-

ably on such work. Between this and the thin sheet there are numberless gradations of work which have never been properly measured by anybody. In stating the opinions of Mr. Hawkins, the compiler does not wish it to appear as though he endorsed all of them. The fact that a watt during a whole hour will generate less than a kilogram calory (more accurately, 0.866), will hardly bear out the contention that it is a question of heating, nor that the popular term "burning at the corners" has anything to do with actual burning by means of heat. In the opinion of the compiler, the limit to the permissible current density is due to the exhaustion of the desired ions in a molecular layer next to the electrode, thus making the solution which is in immediate contact with the electrode, very dilute, and since it is only from this molecular layer, which is in actual contact with the electrode, that the ions are deposited, the density of the rest of the solution does not come into consideration. It therefore seems that rapid circulation for quickly replacing this exhausted layer is that which will enable the current density to be increased.

*Metallic Deposits by Contact.*—Metallic deposits can be produced on metallic objects by using certain electrolytic baths in which the objects are subjected to the action of the bath in contact with zinc, aluminium or magnesium. Darlay, in the *Electrochem. Zeit.*, September, states that no practical result can be gotten in this way, as the baths which were used in connection with aluminium always had an acid character. If such an acid bath is used, the aluminium is attacked, thereby an electric current is generated and a metallic deposit is produced at the surface of the objects to be plated; but this action soon stops, the aluminium is not attacked any more and no more metal is deposited. It is stated that such baths can be used successfully if the acid baths are replaced by others of a strongly alkaline character. Solutions are recommended consisting of a chloride of the metal to be deposited, of ammonium chloride, and of a large excess of an alkaline phosphate or pyrophosphate, with or without the addition of ammonium carbonate. Solutions of a double chloride of ammonium and the metal to be deposited can also be used, with a large excess of alkaline phosphate with or without ammonium carbonate. The following compositions of baths are given: For nickeling, water 25 liters, nickel chloride 500 grams, ammonium chloride 500 grams, sodium pyrophosphate 4 kilograms, and ammonium carbonate 200 grams; or water 10 liters, nickel ammonium chloride 500 grams, sodium pyrophosphate 2 kilograms, and ammonium carbonate 300 grams.

### Theoretical and Experimental.

*Electrolytic Production of Several Plumbic Salts.*—A new method for the production of plumbic chloride is described by Elbs and Nuebling, in the *Zeit. f. Electrochemie*, Sept. 17. The vessel in which the electrolysis is carried out is of glass, and contains a porous cell suspended in it. The apparatus is illustrated in the adjoining figure. A sheet of lead is suspended in the porous cell and serves as cathode. On both sides of the porous cell there are arranged two anodes *B* formed of strips of lead, bent into zig-zag shape; another anode of carbon *A* rests on the bottom of the vessel. The electrolyte in the cathode compartment consists of dilute hydrochloric acid of about 1.1 spec. grav., while the same acid of 1.18 spec. grav. is used as anode liquid. The carbon anode receives about the same amount of current as the two lead anodes, which is controlled by rheostats and ammeters in the two branches of the current. The mean current density at the lead anodes, counting both surfaces, is 0.6 to 0.8 amp. per sq. dm., and at the carbon anode 4 amp. per sq. dm. The temperature of the bath must be below 10° C., and it is therefore cooled with ice on the outside of the vessel. For each liter of anode liquid there are introduced 20 to 25 ampere hours; the yield in plumbic chloride hydrochloric acid $H_2PbCl_6$, obtained is then 70 to 80 per cent of the theoretical. A further continuation of the electrolysis is stated to be disadvantageous, on account of the rapid decrease in yield, because the acid formed takes part in increasing degree in the electrolysis. During electrolysis only a feeble development of chlorine takes place and the anodic liquid is colored orange yellow. The hydrochloric acid solution of plumbic chloride can be kept in closed bottles for any length of time; in open vessels it slowly but gradually gives off free chlorine with the separation of plumbic chloride. The method of determining the yield of plumbic chloride is briefly outlined by the author, who then gives a description of several double salts of plumbic chloride which they prepared. Ammonium plumbic chloride, pyridene plumbic chloride, and chinolene plumbic chloride are described.

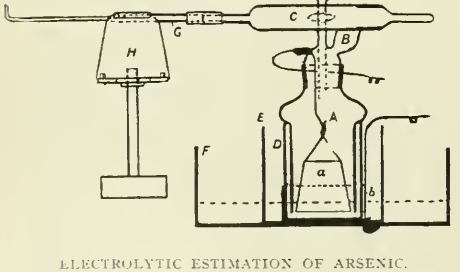


ELECTROLYTIC PRODUCTION OF PLUMBIC SALTS.

The authors then tried hydrobromic acid under the same conditions as were found favorable for the production of lead tetrachloride, with a view to get lead tetrabromide, but they did not succed in getting more than lead dibromide and free bromine. Hydriodic acid was also tried, to see whether they could get lead tetraiodide, but the electrolysis of 1.42 spec. grav. hydriodic acid could never be continued for any length of time, because the resistance increased greatly on account of the formation of a thick layer of lead iodide on the anode. The brown anodic liquor is saturated with lead iodide, which separates on the addition of water. A watery solution of pyridine hydro-iodide produces a grayish green, crystalline precipitate, which finally yields the double salt $2C_5H_5NHI$ $PbI_4$. The chinolene hydro-iodide furnishes also the corresponding double salt. The authors also tried watery solutions of pure chromic anhydride, free from sulphuric acid as electrolyte. Electrolysis was conducted in a glass vessel with a semi-cylindrical anode of lead, a porous cell and a lead cathode in the latter. The temperature was kept between 15° and 20° C. by cooling the vessel on the outside. If the solution of chromic acid is very dilute, as about 0.1 per cent, the lead anode is attacked and chrome yellow is formed, and if the chromic acid content of the electrolyte is kept constant by adding the acid as it is used up, the yield of chrome yellow is nearly quantitative. If the concentration of chromic acid increases to about 1 per cent, a firmly adhering layer of chromate of lead is deposited on the anode, which prevents the passage of the current in a short time. If the contents of chromic acid reach several per cent, the passage of the current is hindered by the chrome yellow formed, but is not prevented, as spots of peroxide of lead appear, at which oxygen is liberated. The more the concentration of chromic acid increases, the more lead peroxide is formed, until the concentration goes beyond 40 or 50 per cent, when the anode slowly becomes soluble again. The authors interpret these results by claiming that in very dilute solutions, plumbous chromate is formed; in moderately dilute solutions, however, a plumbic chromate appears also which, however, is immediately hydrolytically dissociated with the separation of lead peroxide. The more the concentration increases, the more the production of plumbic chloride is favored and its hydrolytic dissociation prevented, so that a considerable quantity is present in the anode liquid. From then on the instability of the pulmbic chloride leads to its decomposition with the solution of oxygen. The authors give

reactions observed by them, which serve to support this theory. They also tried ortho-phosphoric acid of 1.75 spec. grav. as anode liquid, with dilute phosphoric acid as cathode electrolyte, and they were able to obtain a plumbic salt of the ortho-phosphoric acid, with an anodic current density of about 1 ampere per sq. dm., at the room temperature. With an electrolyte of a 17 to 20 per cent solution of hydrofluosilicic acid and a current density of about 1 ampere per sq. dm., the anode is dissolved without the formation of a precipitate and lead is deposited almost quantitatively at the cathode. No plumbic salt was obtained with an arrangement similar to that used for the production of lead tetrachloride.

*Electrolytic Estimation of Minute Quantities of Arsenic.*—A method for the electrolytic estimation of minute quantities of arsenic has been worked out by Thorpe, and is published in the *Electrochemist and Metallurgist*, September. It is intended more especially for the analysis of brewing materials. The apparatus used is illustrated in the adjoining figure. It consists of a glass vessel *A* which forms with the porous vessel *D* the inner cell for the cathode, where the hydrogen and hydrogen arsenide are produced on passing the current. *A* is open at the bottom and fitted at the top with a ground-glass stopper, through which is passed the stem of a tap-funnel. The glass stopper also carries a bulbed exit tube, connected with the drying tube *C*. The cathode is of platinum and is cone shaped with several perforations. The anode cell consists of a glass vessel *E*, and the anode is a platinum band passing loosely around the porous cell. A constricted tube of hard glass is connected to the drying vessel *C* and supported on the mantel of a small Bunsen burner, *H*. The arsenic is to be deposited in this tube. The methods for preparing the




ELECTROLYTIC ESTIMATION OF ARSENIC.

extracts or solutions of the various substances, such as malt, wort, hops, beer, etc., are given in detail, and the manipulation of the apparatus is described. The reaction depends on the evolution of the arsenic contained in the substance under investigation, and which is introduced into the cathode compartment of the apparatus, as arseniuretted hydrogen and the deposition of a mirror of arsenic in the hard glass tube. These deposits are then compared with similar deposits obtained by the electrolysis of solutions which contained a known amount of arsenic. The advantages of the electrolytic method are as follows: 1, it does away with the use of zinc; 2, it is simple in operation, is under perfect control, and may be carried out under such conditions that the results obtained by different operators are strictly comparable, inasmuch as with a current strength of fair regularity the evolution of the gas is practically constant and uniform; 3, the whole of the solution to be tested for arsenic may be added at once, so that during the whole time of testing the arsenic is under the influence of "nascent" hydrogen; 4, it has been established that such amounts of arsenic as are present in beer or its ingredients are evolved as hydrogen arsenide during the thirty minutes occupied by the test. The nature of the material associated with the arsenic is found to exercise no inhibiting effect on the formation and evolution of the hydrogen arsenide. Aqueous extracts of malt or worts may be added directly to the electrolytic apparatus without previous destruction of the organic material as required by the zinc and acid process; 5, the deposits obtained are more uniform in character than those furnished by the zinc and acid method, and admit therefore of more accurate quantitative comparison.

*Double Electric Layer and Absolute Potential.*—According to Billitzer, if a difference of potential is applied at a region where the double layer is present, the ponderomotive forces exerted by the electric field on the two parts of the double layer, are opposite. A relative displacement of the two layers must therefore take place, and this displacement will change direction with the sign of the double layer and will disappear with the latter. Fine metallic wires of 0.01 to 0.05 mm. diameter are fused at their ends so as to form small globules. They are suspended at their other ends from a thread of quartz between two electrodes, between which is established a difference of potential of 220, 158.72, or 10 volts. The displacements of the thread are observed by means of a microscope. He has observed these and similar phenomena and gives the results of his investigations in *Drude's Annalen*, July, 1903, an abstract of which is given in *L'Eclairage Electrique* of September 5. Platinum charged with hydrogen is negative towards solutions which are weakly acid or alkaline; if charged with hydrogen, it is negative towards weakly alkaline solutions and positive towards acid solutions. Solutions which contain ferrous and ferric ions at the same time are well adapted for the determination of the point of inversion. The absolute concentration of the salts has no influence, but only the ratio of the concentrations of the two kinds of ions. The experiment succeeds also with a solution of formaldehyde, of ethyl alcohol and of oxygenated water. The inversion is produced when the difference of potential between the metal dipped into the solution and a calomel normal electrode is in the neighborhood of 0.12 volts. With mercury the inversion is obtained with difficulty on the addition of mercuric nitrate to the solution. Silver dipped into a solution of nitrate of silver of increasing concentration does not give any inversion. Whichever be the metal and the method employed, it is found for platinum, gold, palladium, silver, mercury, copper and iron, that the point of inversion corresponds to a difference of potential of 0.4 volts (towards hydrogen). This result is not modified by the use of complex salts. These results are explainable with difficulty, if the definition of the double layer as given by Helmholtz is adopted; it is particularly difficult to conciliate them with the idea of two layers of opposite sign.

*Vaporization and Boiling of Metals.*—The vaporization and the boiling of metals in quartz vessels and in the electric furnace at the "vacuum of the cathode light," has been investigated by Krafft, and the results are published in the *Berichte der Deutsch. Chem. Ges.*, 36, 1690-1714. An abstract is given in the *Zeit. f. Electrochem.*, September 17. The author used several forms of quartz vessels, the thin-walled ones being used up to 1200° C, the thick-walled ones to 1400° C. For the metal zinc he found a rapid sublimation at 430° C, which continued to an appreciable degree down to 300°. Quick distillation, accompanied by ebullition, took place at 640° C, 5 grams only taking 30 minutes to vaporize; the boiling zinc seemed to show the Leidenfrost phenomenon. Cadmium showed appreciable vaporization as low as 320°, slow distillation at 450°, and ebullition with Leidenfrost phenomenon and rapid distillation at 470° C (about 3 grams in 20 minutes). Selenium was easily volatile at 380°. Tellurium was shown to be appreciably volatile at 430°; strong ebullition and rapid distillation (about 2 grams in 25 minutes) taking place at 540°. With lead, appreciable vaporization showed itself at 800°, strong ebullition at 1160° and distillation of 1.2 grams in about 10 minutes. Tin at 1100° did not show any traces of volatiliza-

tion. Antimony at 670° was appreciably volatile; at 780° rapid distillation showed itself (3.5 grams in about 20 minutes). Bismuth is already volatile at 540°, and 3 grams volatilized in about 15 minutes at 1050°. At 1200° therefore, very closely above the melting point, silver showed appreciable vaporization; at 1340° rapid vaporization took place (0.09 gram in about 12 minutes); ebullition was not reached. Copper showed appreciable volatilization at 1315°, but it was appreciably less than with silver. Gold at 1375° shows appreciable vaporization, but very slowly. The boiling points for the conditions under which the author worked were found to be for zinc about 550°, bismuth about 1000°, antimony about 735°, and lead about 1140°.

*Chemical Valency, Electrical Conductivity and Hardness of Metals.*—Molecular combinations of electrolytes in solution, which are practically in the gaseous state, according to Van't Hoff's theory as enlarged by Arrhenius, have the same ultimate electric capacity with varying valencies. In an article in the *Electrochemist and Metallurgist*, September, RHODIN extends this law to substances in other forms of aggregation, with special reference to metallic solids. He looks upon the electrical conductivity of a metal as caused by the transfer of electricity from one section of the conductor to another by means of the motion of the molecular combinations of which it is composed. As a consequence of a mathematical investigation, he comes to the conclusion that a hard metal has more complicated molecules than a soft one. To elucidate the difference between metallic conductors and all other substances, he puts down the following criteria: 1. All metallic conductors are composed of ultimate particles, which can act as cations during electrolysis without the intervention of other elements. The ultimate particles are thus electrically uniform. 2. All electrolytic conductors are composed of ultimate particles of two kinds, viz., one or more cations and one or more anions, which readily dissociate by the influence of a solvent or fusion. They are thus electrically binary. 3. All dielectrics are characterized by an exceptional resistance offered by their ultimate particles against molecular motion, depending upon either the exceptional size and mass of its molecular combinations, if solid, or internal friction, if liquid. They are electrochemically uniform. 4. The electrical behavior of any substance is a function of the absolute temperature.

GENERAL AND MISCELLANEOUS.

*Magnetic Separation of Ores.*—A few of the latest types of the well-known Wetherill separators, as built by the Metallurgische Gesell-chaft, of Frankfort, Germany, are briefly described and diagrammatically illustrated by FABRE in *L'Echairage Electrique*, September 5. The first type shows an electromagnet system with poles tapering to an edge and having two south poles opposed to a north pole. This type is intended for the treatment of feebly magnetic minerals. The ore is carried on a belt, which moves towards the poles; directly in front of the pole the belt passes down over a small pulley and the ore therefor falls from the belt while under the influence of the magnetic field. The magnetic constituents are attracted towards the magnets above the belt and are carried past them on the lower side of a second belt which travels directly under the magnet. According to the strength of the magnetic particles they are carried more or less far, and fall into different reservoirs. For the separation of spathic iron ore from blende, it is stated that 1 kw-hour suffices for the treatment of 1000 kilograms of material. In the second type the magnetic materials are attracted towards a belt moving over the magnets at right angles to the feeder belt. The third type presents a cylindrical separator, the magnetic system of which consists of a cylinder composed of discs of rings, which turn between the poles of a magnet. The material to be separated falls upon this revolving cylinder, which becomes magnetic by induction, and carries the magnetic materials around with it according to their permeability.

*Aluminium as an Electrical Conductor.*—A paper on the above subject was read by KERSHAW before the recent annual meeting of the British Association for the Advancement of Science, and is reprinted in the *London Electrical Review*, Sept. 18. In the first part the author gives statistics on the production of aluminium, a calculation of the relative cost of copper and aluminium, and a short review of recent installations where aluminium has been used as conductor. He then describes a test which he made, and which extended over a period from October, 1899, to December, 1902. Rods and wires, cut into two feet length, were mounted in horizontal frames and exposed to the action of the atmosphere. Tables of the results obtained are given in the article. The summary of the results shows that all the samples of aluminium gained in weight during exposure, and that all were pitted and corroded, especially on the under side, where the water drops had collected and dried. The rods seemed to have suffered less than the wires, and the author therefore thinks it probable that in the course of drawing it down to wire, the aluminium undergoes a physical change. One sample of aluminium, purer than the others, was, nevertheless, badly corroded at the end of one year's exposure. The author states in conclusion that he does not wish to base any unfair conclusions upon these results. He claims, however, to have proved that some of the aluminium rod and wire which was being manufactured and sold in England for electrical purposes in the year 1899 and 1901 was not able to stand atmospheric exposure on the coast of Lancashire without corrosion. It is only a fair deduction from these exposure tests to assert in the opinion of the author, that aluminium manufacturers have yet to prove the metal to be a satisfactory and durable substitute for copper in bare overhead transmission lines, or for electrical work which involves exposure to climates near the coast. It is no more than fair to say that there are numerous chemical works in that district. Mr. Kershaw's observations of the deterioration of aluminium might also be explained by the fact that there is much carbon dust in the air from the smoke, and that carbon in contact with aluminium, especially when wet with salt water, or rain water containing the chlorine or hydrochloric acid vapors from chemical works, will form a strong battery in which the aluminium is consumed.

*Some Alloys of Copper and Aluminium.*—The measurement of the thermic effect, which accompanies the formation of copper and aluminium alloys, presents great difficulties, as far as a suitable reagent was concerned, which would act upon both metals of the alloys. LEBEAU NINE and SCHUKAREFF succeeded by using a solution of bromine in potassium bromide. The results of their work are given in detail in the new *Journal de Chimie Physique*, Vol. 1, No. 1, July. They have investigated the alloys $Cu_3Al$, $Cu_2Al$, $CuAl_2$, $CuAl$, $Cu_2Al_3$ and $CuAl_4$. Higher percentages than 50 per cent of aluminium in the alloys could not be investigated, as the reagent no longer acted with such high amounts of aluminium. The apparatus used by the authors is illustrated in the article, and the various steps in the investigation are set forth at length. They find for the heat of formation of $Cu_3Al$ 123.5 cal., $Cu_2Al$ 137.9 cal., $CuAl$ 71.0 cal., $CuAl_2$ 50.8 cal., $Cu_2Al_3$ 48.9 cal., and $CuAl_4$ 37.2 cal. Presumably these numbers refer to kilogram calories and gram molecules.

*Experiments with Acetylene Lighting in Mines.*—A long report made by the German government commission on the question of acetylene lighting in mines, especially coal mines, is investigated in detail, and the various types of acetylene lamps in use in Germany are described. The conclusions indicate that the acetylene lamp is not yet beyond the stage of experimental development, where they can be handled with safety by the miner. Compressed acetylene in the hands of mine foremen and officials for control purposes. *Zeit. f. Carbid- u. Acetylen.*, September 11, 18, 25.

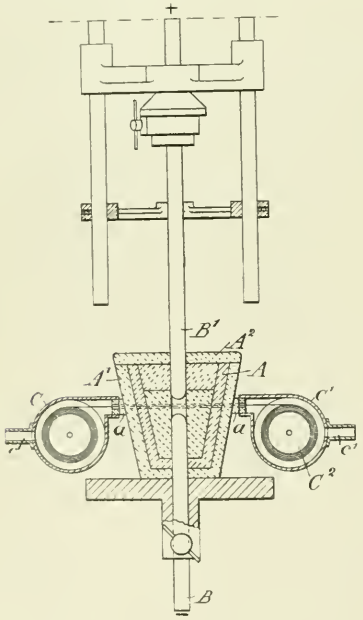
# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

Electric Furnaces and Furnace Products.

*Electric Furnace for the Manufacture of Filaments.*—W. L. Voelker, Erie, Pa. Patent 740,379, September 29, 1903. Original application filed March 15, 1902. Divided and refiled April 10, 1903.

The furnace described in the specification is intended to be used for the manufacture of filaments for incandescent electric lamps. It consists essentially of a black-lead vessel A, crucible-shaped and enclosed in an outer vessel $A_1$ of refractory materials. Two opposing sides of the inner vessel are provided with perforated extensions a, a, which pass through openings in the outer vessel. A drum C, $C_1$ is mounted opposite each of the extensions, on which the filament is wound. The latter passes from one drum into the corresponding passage a, then through the interior of the graphite crucible




FURNACE FOR MAKING FILAMENTS.

and out at the opposite side through the other passage a, to the second drum. The arc is struck between a pair of vertical electrodes B, $B_1$, and the carbon filament does not pass directly in the center line of the electrodes, but somewhat to the front of them, the wall of the crucible being hollowed out for that purpose. The arc is deflected into this hollow and onto the filament by means of a magnet. In making a graphite filament the interior of the furnace is lined with a consolidated purified sugar carbon, which extends about half-way up the crucible. Above that the inventor places a highly refractory oxide, such as thorium oxide. The cover $A_2$ is then put on, the arc struck between the electrodes and the interior of the furnace brought to a white heat, after which the filament is drawn through. If it is desired to form a filament composed of the carbides of certain metals, the filament may or may not be treated with a solution of the metallic salts previous to drawing it through the furnace. In this case it is necessary to line the entire crucible with the oxide of the selected metal or metals, and before passing the filament through the furnace, the lining immediately surrounding the arc must be converted into a carbide and then into a metal. What particular carbides he proposes to use, is not disclosed by the inventor. The furnace is so arranged that gases may be passed into the interior of the furnace, by connecting the passages c, $c_1$ with the gas supply.

Electrolytic Production of Metals and Compounds.

*Electrolytic Diaphragm.* E. A. Byrnes, Washington, D. C. Patent 735,404, August 4, 1903. Application filed May 12, 1903.

The diaphragm described in the specification is primarily intended for the electrolysis of alkali metal compounds, but is capable of general application. The diaphragm consists essentially of fragments of a suitable size of an electrically conductive material. The thickness of the layer depends on the requirements of the special case in which it is employed. It may be supported by placing it between sheets of a foraminous material or by incorporating with it a suitable amount of an inert binder in order to make it self-supporting. If the cell has a cathode of molten lead the diaphragm may rest directly upon the molten material. In the case of the electrolysis of brine, a cell is described which has a diaphragm of magnetite or ferroferric oxide. It is stated that this will resist the action of alkaline chlorides and nitrates and their electrolytic products Ilmenite or chromite are stated to be also available, and broken glass or porcelain to be suitable for use in aqueous electrolytes. The fragments may be of a size to pass a fifty mesh sieve, and the layer itself may be from one to several inches thick. Several forms of application of the diaphragm are described.

*Electrolytic Process of Recovering Metals from Their Compounds.* C. E. Baker and A. W. Burwell, Cleveland, Ohio. Patent 730,130, September 15, 1903. Application filed November 11, 1902.

This process consists in the electrolysis of sodium chloride, the absorption of the sodium in a mercury cathode and the subsequent distillation of mercury in order to effect the recovery of the sodium. The process is carried out in the apparatus, which has been described at length in Electrochemical Industry, Vol. I., p. 460, with illustration. The latter is reproduced in the specification under consideration.

*Apparatus for Oxidizing Metals Dissolved in Mercury.* C. E. Baker and A. W. Burwell, Cleveland, Ohio. Patent 739,140, September 15, 1903. Application filed November 11, 1902.

This invention deals with a process of discharging sodium from its amalgam with mercury, after it has been introduced into the latter during the electrolysis of sodium chloride. The apparatus described consists of a rectangular vessel for receiving the amalgam, which latter is covered with a layer of water, the water and the amalgam being kept in continuous movement in opposite directions. A number of roughened pieces of carbon are placed in contact with the amalgam and the water, each body of carbon serving to cause a vigorous reaction between the sodium in the amalgam and the water. The inventors have found that carbon bodies which are produced by forcing a plastic mixture of hydrocarbons and carbon through a die and baking the resultant product, are entirely unsuitable for use in this connection. This is attributed to a thin outer layer of substantially pure carbon, which is formed on the outer sur-

face of the objects which does not come into satisfactory metallic contact with the mercury. If this original surface, however, is removed by mechanical means and the inner portion exposed, the latter is readily wetted by the mercury.

*Method of Electrodepositing Metals.* C. R. Fletcher, Boston. Patent 740,359, September 29, 1903. Application filed May 28, 1900.

The specification describes a method for the more rapid and uniform coating of metallic sheets, brought about by rotating the cathode. The apparatus proposed by the inventor consists essentially of a rectangular vat, in which a sort of a cage of metal is suspended from a roller, which can be rotated. This cage, called by the inventor the cathode base, is formed of several rings of metal, preferably of copper or brass, held together by metallic rods. The cages serve for the support of the sheets to be electroplated, which are fastened to them by means described in detail in the specification. The sheets receive deposit from both sides, there being an anode arranged inside of the cage and another one outside of it. The inventor states that for this purpose he employs by preference two independent sources of electricity, for the reason that with them the volume and the pressure of the currents can be better sustained than by using resistance coils, which exert a varying influence on the current as they become heated, and therefore require constant attention, when work is carried out on a practical scale. The advantage of the rotary cathode is, of course, the possibility of carrying a greater current density for plating purposes than is possible with a stationary one.

*Art of Making Bleaching Compound.* Marcus Ruthenburg, Harrisburg, Pa. Patent 739,448, September 22, 1903. Application filed January 14, 1902.

The process consists in the electrolysis of a 20 per cent solution of sodium chloride, mixed with an aqueous solution containing 10 per cent of hydrated oxide of lime. The current density is half an ampere per square inch of the electrode surface exposed to the solution, and the pressure is three volts. The material of which the electrodes are composed is not disclosed. The oxide of calcium is employed by preference on account of its low cost, but the oxides of magnesium, lithium, aluminium, sodium and potassium may also be used. It is claimed as advantages of the process that the hydrated oxide of lime prevents the escape of chlorine from the solution during electrolysis, and that it has the effect of increasing the conductivity of the electrolyte.

STORAGE BATTERIES.

*Method of Treating Lead Plates for Use in Secondary Batteries.* C. J. Reed, Philadelphia. Patent 735,820, August 11, 1903. Application filed February 1, 1902.

The method outlined in the specification consists in subjecting a plate of metallic lead in a closed chamber to the action of hydrochloric acid gas, preferably mixed with an oxidizing agent, as nitric acid, nitric oxide, nitric peroxide, chlorine or bromine. The hydrochloric acid gas may be mixed with those oxidizing agents before entering the treating chamber, or they may be introduced separately. The former method is preferred. The formation of lead chloride is stated to be much promoted if the surface of the plate under treatment is kept in a moist condition. The plates are moistened as soon as they become dry, through the action of the gases by submerging them in water or in a solution containing hydrochloric or nitric acid. The time between the applications of the moistening liquid may vary from 2 to 5 hours. A vessel is provided in conjunction with the treating chamber, which vessel contains the solution, and from which a sufficient amount of the latter is forced by air pressure into the treating chamber. After the pressure is released, the solution flows back into the reservoir by syphon action. It is preferred to convert the chloride of lead thus formed into spongy lead by contact with zinc in a solution of zinc chloride, and to subsequently oxidize them by the ordinary process of charging.

*Secondary Battery Plate and Method of Making Same.* A. F. Clark, Philadelphia. Patent 736,217, August 11, 1903. Application filed December 28, 1901.

The specification illustrates and describes a process for making battery plates of a grid shape. The plates are formed in two operations, the first mould being of such shape, that the spaces between the gridbars can be filled with active material after the first compression. In the second operation the gridbars, with the active material between them, are flattened out in such a manner that the active material is securely held. An apparatus for rolling down the plates into the desired shape is shown in the specification.

*Storage Battery.* A. V. Meserole, New York. Patent 736,125, August 11, 1903. Application filed May 14, 1903.

The cell described in this specification consists of a containing vessel of any desired insulating material, which contains two electrodes of peculiar construction. One electrode consists of a metallic ring, placed on the bottom of the vessel, integral with which are cast a number of tubes of the same material as the ring, and projecting upward. One of these tubes is much longer than the others, and serves for the purpose of making the electrical connection. Each two of the tubes carry a set of peculiarly shaped bodies, called "wafers" by the inventor. They are formed by spreading the active material in the form of a plastic paste into thin layers, each of which is preferably of the consistency of stiff dough. A number of these layers are placed on top of each other, a sheet of metal is placed at the top and bottom of the pile, and other layers are added, so that the whole forms a composite structure consisting of a metal sheet at the top, several layers of active material, another sheet of metal, some more layers of active material, etc. The desired shape is then cut out from the superimposed sheets by means of a stamp. For the outer electrode they are preferably in the shape of a kidney, while the ones forming the central electrode are annular. The latter are mounted upon a single tube, much larger in diameter than those of the outer electrode, and serving as the second electrical connection. It is claimed that by constructing these "wafers," the active material is disposed to better advantage, and that expansion and contraction are provided for

*Separator for Secondary Batteries.* A. F. Clark, Philadelphia. Patent 736,216, August 11, 1903. Application filed July 22, 1901.

The separator is adapted for use with the inventor's type of battery, as described in the preceding specification. It is formed of some non-conducting material capable of being molded, as hard rubber, porcelain, earthenware, celluloid, etc. The separator is made up of a series of cross-bars, shaped so as to enter a space between the grates of the grid, mentioned in the description of the above cell, which constitutes the framework of the electrodes, and the active material. The cross-bars of the separator are held together by means of ribs of triangular cross section. Several modifications of the construction are described.

*Secondary Battery.* G. E. Hatch, Quincy, Mass. Patent 738,188, September 8, 1903. Application filed February 13, 1899.

The negative electrodes of this battery are constructed by filling red lead into thin porous plates, formed in the shape of a shallow tray on both sides. These plates are made of thin, porous wood, and are provided with a number of holes. The positive electrodes are composed of a rigid porous support plate, preferably made of kaolin or a similar acid resisting material containing no iron, which are provided with a number of parallel grooves. The grooves on one side of the plate are filled with active material in the form of a paste as usual. Conducting plates are employed, made from thin sheets of metallic lead and provided with a number of perforations, designed to serve as reservoirs for the electrolyte. The cells are built up by placing a positive plate with its pasted side against a conducting plate, the grooves being vertical for the

purpose of circulation of the electrolyte. A pasted negative plate is placed against the other side of the positive plate, facing the non-conducting support plate of the latter, and a conducting plate is placed in turn on the other side of the negative plate. The couples are held together by glass or other acid-resisting plates on the outside, held in position by rubber bands.

*Process of Producing Active Material and Electrodes for Storage Batteries and Products Thereof.* O. P. Fritchle, Denver. Patent 738,313, September 8, 1903. Application filed January 7, 1903.

This invention is stated to be based on the discovery that granulated lead, if sprayed into a hot solution of hydrochloric acid, obtains a peculiar cohesive property, and can be easily compressed by comparatively slight pressure into a rigid but highly porous mass. An apparatus for carrying out this invention is described in the specification. The hydrochloric acid used is preferably a 5 per cent solution; a solution of any other acid, salt or compound which will yield chlorine to the lead, or chlorine water, or chlorine itself, may be employed. It is said to be important that the treated lead should be compressed without delay, as its property of welding is soon destroyed by the action of the acid. The granulated lead should have a fineness of between 60 and 100 mesh. To granulated lead after passing through the acid may be received directly on the bottom of any suitable vessel and compressed into a highly porous and self-supporting electrode of sufficient rigidity for practical use.

*Apparatus for Producing Active Material and Electrodes for Storage Batteries.* O. P. Fritchle, Denver. Patent 738,314, September 8, 1903. Application filed January 7, 1903.

This specification patents the apparatus, identical with that shown in the preceeding one, for carrying out the process described above.

*Process of Producing Active Material and Electrodes for Storage Batteries and Product Thereof.* O. P. Fritchle, Denver. Patent 738,427, September 8, 1903. Application filed March 18, 1903.

In this specification it is claimed that finely divided lead obtains a peculiar cohesive property also when sprayed into a hot dilute solution of acetic or nitric acid, or of sodium or potassium hydroxide. The apparatus for carrying out the process is the same as that described in the preceding specification.

*Storage Battery.* F. A. Redmon, Chicago. Patent 738,942, September 15, 1903. Application filed March 16, 1903.

The plates of this battery are constructed in the following manner. A perforated metallic blank is provided, consisting of two portions united by an unperforated part. One portion of the blank has wider margins than the other. The active material is spread upon an absorbent substance like burlap, matting or a similar fibrous material. This treated material is then placed upon that portion of the blank which has the narrower margin, and the other portion bent about and placed over it, the wider margins of the latter serving to be folded over the edges of the smaller portion of the plate so as to form a pocket. The structure is then placed between dies and compressed and corrugated at the same time. Any desired number of these plates may be assembled to form a battery, by spacing them apart by a separator, composed of a perforated sheet of insulating material corrugated transversely with respect to the corrugations in the plate.

*Terminal for Storage Batteries.* J. W. Madigin, Toronto, Canada. Patent 739,432, September 22, 1903. Application filed January 10, 1903.

The terminal construction described in the specification is arranged with a view to provide a non-corrodible connection. An iron bolt is cast into the terminal, into which is screwed a leaden nut, which contains an iron nut within it. When the nut is screwed home, it holds in place a ring of lead, into which the end of the connecting wire is cast. No iron surfaces are, therefore, exposed.

*Storage Battery.* J. T. Niblett, Greenwich, London, England. Patent 740,034, September 29, 1903. Application filed August 8, 1902.

The invention is intended to improve both the active material of the plates and the porous separators. It consists in adding to the active material of the plates, and to the substances from which the separators are made, a certain amount of infusorial earth, "kieselguhr." It is claimed that the mixing of kieselguhr with the active material brings about a great degree of permeability of the resulting plates, the fibers of the kieselguhr acting as minute ducts to convey the electrolyte into the body of the material by capillary attraction. The proportion of kieselguhr may be 1 to 5 per cent for the positive, and 2½ per cent for the negative plates. It is claimed that very satisfactory plates may be made up of about equal parts of litharge and red lead, mixed with 2½ per cent of kieselguhr and then molded into the desired shape. The separators are formed wholly or principally of kieselguhr wetted with f. e. sodium silicate, and molded into thin slabs, which are burned to render them hard and firm.

On account of limitations of space a large number of patents had to be reserved for our next issue.

## NEW YORK SECTION OF THE AMERICAN ELECTROCHEMICAL SOCIETY.

At the recent meeting of the American Electrochemical Society in Niagara Falls, the formation of local sections was approved by the Board of Directors, the first local branch to be established at Madison, Wis. Members from New York attending the meeting informally expressed themselves in favor of the formation of a New York Section. In consequence of this Mr. Alois von Isakovics sent out a circular letter to all members in New York City, and vicinity within 20 miles, to attend a preliminary meeting at the Chemists' Club on October 10, for considering the advisability of organizing a New York Section. Owing to very bad weather the attendance was small (but not smaller than at the first preliminary meeting held in Philadelphia in 1901, at which the advisability of the formation of the American Electrochemical Society was considered). A larger number of New York members, however, had expressed their approval of the scheme by letter or telephone messages. After some discussion, in which Dr. C. A. Doremus, Dr. H. Poole, Dr. G. W. Maynard, Mr. J. Bijur, Mr. A. von Isakovics and others participated, the formation of the section was unanimously approved, and Dr. C. A. Doremus was elected chairman and Mr. A. von Isakovics secretary. The date of the first meeting has not yet been decided, but it is probable that at this occasion Dr. Doremus will speak on the very elaborate equipment of the chemical laboratories of the new College of the City of New York. It was also proposed that several short papers of, say, five or ten minutes, should be read at one session. In such short and more informal talks the speakers could discuss questions which come up in their practice, and which they do not think important enough for preparing an elaborate paper before the general society. It is hoped that such informal talks will bring out very good discussions, and that the sessions of the New York Section of the American Electrochemical Society may become a rendezvous, not only for electrochemists, but for chemists, electrical engineers and mining and metallurgical engineers in general, and will do a great deal toward bringing these various classes of engineers together.

The business of the Section will be conducted by an executive committee of five members, consisting of the chairman and the secretary, and three members to be appointed by the chairman. Invitations to the first meeting will be duly sent by the secretary to all members in New York City and vicinity.

# Correspondence.

## CYANIDE SILVER PLATING BATHS.

To the Editor of Electrochemical Industry.

Sir—I would like to reply to Mr. Hering's remarks on my communication (page 514 of your October number) in which he takes issue with me in regard to certain statements by Messrs. Jordis and Stramer, as to the loss of "cyanide" and increase of carbonate in the plating baths referred to, and in which he claims that the "contradiction" I pointed out does not exist, because the authors quoted do not specify the "ratio of such loss and increase." Now, in my remarks I said nothing whatever about "ratio." My contention was, and is, that the loss of cyanogen does not result in an increase of "carbonate," as the authors state, for the simple reason that the equivalent of CN which passes off and constitutes the loss complained of by electroplaters, leaves the equivalent of potassic carbonate with which it was combined in the bath, no more and no less. Hence, the increase of "carbonate" which they refer to could not possibly take place. If the authors named had merely stated that the loss of cyanogen was greater with a working solution than with an idle one, the statement would have been in accordance with the experience of every silver plater. But there could be no increase of potassic carbonate as they intimate. In the latter part of their article quoted by Mr. Hering, they say: "It has been found that after a while more cyanide disappears than is equivalent to the amount of carbonate found." Here is where the contradiction comes in. If a thing or part of a thing can't be found then it must have been lost, or disappeared. Taking the two declarations of Messrs. Jordis and Stramer on the "carbonate" question, if they do not constitute a contradiction, I fail to see what arrangement of words would. The fact is that their statements on the "carbonate" matter are both wrong. There is neither increase nor decrease.

The closing declaration of Mr. Hering that "the loss of cyanogen necessarily involves a loss of cyanide" is not in accordance with the facts, because argento potassic-cyanide is a definite fixed salt, but all cyanide plating solutions require a certain amount of free cyanogen to ensure a good working condition during electrolysis, enough to effectually and continuously dissolve the oxide formed on the anodes during the process of electrolysis. It is this constant and rapid loss of "free" cyanogen that gives the electro-silver plater so much trouble, but the fixed salt is comparatively unaltered. Hence, whatever the loss of "free" cyanogen which may occur in a plating bath, the "cyanide" is there all the same, though the solution may not work satisfactorily when in this state. But just add a little HCN gas or liquid, and the solution will, under electrolysis, immediately dissolve the oxide from the anode and deposit its metal on the cathode as freely as before. Loss of cyanogen does not necessarily involve loss of "cyanide."

Cincinnati, Ohio. James Powell.

## A SUBOXIDE OF SILICON.

To the Editor of Electrochemical Industry.

Sir—I wish to say a few words in connection with the note of Mr. F. A. J. FitzGerald on "an alleged suboxide of silicon," published in your October issue, page 514. At the time the work was done on this substance, I knew of the work of Colson and Schuetzenberger, and I recollect that we tested for the presence of carbon in the substance analyzed with a negative result.

Mr. H. L. Payne, who assisted me in a part of the work, has the same recollection. Unfortunately, all notes relating to that work were destroyed by fire soon after the experiments were made, as well as the material. The description of these results is given in the *American Chemical Journal*, 1887, page 14.

C. F. Mabery

Cleveland, Ohio.

## DATA CONCERNING PLATINUM.

Messrs. Baker & Co., the well-known gold, silver and platinum refiners, of Newark, N. J., have just issued the eleventh edition of their booklet, "Data Concerning Platinum."

The following notes on the use and care of platinum ware should be of general interest. Although platinum is not oxidized in the air at any temperature nor attacked by any single acid, yet there are many substances that attack and combine with it at comparatively low temperatures. The caustic alkalies, the alkaline earths, nitrates and cyanides, and especially the hydrates of barium and lithium, attack platinum at a red heat, although the alkaline carbonates have no effect at the highest temperatures. Sulphur, in the absence of alkalies, has no action, but phosphorus and arsenic attack platinum when heated with it.

Direct contact of platinum with burning charcoal should be avoided, since the silicon reduced from the charcoal ash unites with platinum, making it brittle and liable to fracture. Also contact with compounds of the easily reducible metals is especially dangerous at high temperatures, as alloys with platinum having a low fusing point are readily formed. This is especially true of lead.

Heating of platinum with spirit lamps is preferable to the use of ordinary gas. When gas is used, care should be taken to have the supply of air sufficient to insure complete combustion, since, with the flame containing free carbon, the platinum suffers deterioration by the formation of a carbide of platinum, which, oxidizing later, blisters the metal. For this reason, also, the inner cone or reducing flame should not be in contact with the metal. The loosening effect of the Bunsen flame upon the surface of platinum exposed to its action produces the familiar gray appearance, which cannot be removed except by burnishing. Platinum triangles often become gray and very brittle from the same cause. Systematic application of moist sand to all articles affected in this way, after use, will keep them in prime condition and materially prolong their life with but a trifling loss in weight.

Every careful analyst of necessity uses clean utensils. A habit of cleaning and polishing platinum dishes immediately after using is easily formed, and repays the user with increased confidence in his work as well as in the prolonged life of the article. Rubbing the surface of platinum with moist sea sand (round grains only), applied with the fingers, serve to remove most impurities and to polish the metal without material loss.

Fusing bisulphate of potash or borax in the dish and then boiling in water and polishing as above with sand is recommended by Gmelin. When it is desired to clean the outer surface of dishes in this manner, they must be placed in dishes of sufficient size to allow the fused flux to completely envelope the article to be cleaned.

Sodium amalgam possesses the property of wetting platinum without amalgamating with it, even when other metals are purposely added to the amalgam. This substance is, therefore, useful for effecting a quick and thorough cleansing of platinum. The amalgam is gently rubbed upon the metal with a cloth and then moistened with water, which oxidizes the sodium and leaves the mercury free to alloy with foreign metals. The mercury is then wiped off and the dish cleaned and polished with sand, as above described.

If the existence of a base metal alloyed with the platinum is suspected, the article in question is first immersed in boiling HCl for a few minutes, then, after thorough rinsing with clean water, immersed in boiling $HNO_3$ free from chlorine. If the dish is unaffected in weight or appearance, and the acid baths fail to give reaction for the base metals, their absence in appreciable quantities is assured.

Besides illustrated descriptions of platinum stills for the concentration of sulphuric acid and of Heward's density regulator, and illustrations of the standard sizes of platinum

dishes, crucibles, retorts, bottles, pots, dipping baskets for jewelers, anodes and cathodes for electrolytic separation, and of the various platinum apparatus for analytic and general laboratory work, the booklet contains a greater number of very valuable tables as follows: atomic weights; comparison of troy, avoirdupois and French weights; comparison of wire gauges; comparative table of lengths, areas, and volumes; conversion of thermometer readings; weight and electrical resistance of copper wire; decimal parts of a millimeter expressed in decimal parts of an inch; diameters of platinum wire fused by electric current of given strength; fractional parts of an inch expressed in thousandths; number of feet of platinum wire per troy ounce; number of square inches of platinum sheet and foil per troy ounce; specific gravity, specific heat, latent heat of fusion, and approximate melting point of metals; density and boiling points of sulphuric acid; weight per foot of platinum wire in troy and French weights; weight per foot of platinum wire in troy ounces; weight per square inch of platinum sheet or foil in ounces, dwts., grains and grammes; weight per square inch of platinum sheet or foil in troy ounces.

The following information concerning fuse wire is of interest. The fact that platinum does not oxide at any temperature greatly increases the surety of the interruption of the electric current only at a predetermined point, and for this reason platinum wires are coming gradually into more extended use for protective fuses in electric circuits of small current capacity, especially telephonic and telegraphic circuits, for which purpose the small section of the fuse wire required renders the cost insignificant. According to a formula of W. H. Preece, the diameter of a platinum wire has the following relation to the current which will fuse it:

$$D = (0.00019335\ C)^{\frac{3}{2}}$$

where D is the diameter of the platinum wire in inches and C the current in amperes required to fuse. The booklet contains a table, based on this formula, giving the diameter in inches for different values of the current for a fixed length of 6 ins. of wire between supporting terminals.

The electric resistance of commercial platinum is approximately ten times that of copper; specific heat = 0.03243 (Regnault), the coefficient of linear expansion at 40° is 0.00000899 (Fizeau), and the coefficient of cubic expansion per degree C. is 0.000026 to 0.000029 (Watts). The booklet is very neat in appearance and should be quite useful to anybody who has to use platinum apparatus.

## PROSPECTING GOLD DREDGE WITH STEEL HULL.

Next to electrolytic copper refining, the treating of gold ores is that field of metallurgy in which electrochemical methods have found the largest commercial application; we refer, of course, to those cyanide processes in which the electric current is used either for dissolving the gold in the cyanide solution or for precipitating it from the same. On the other hand, the chemical method of precipitating gold from a cyanide solution by means of zinc shavings is at least of equal commercial importance, while the purely mechanical processes of treating ore or sand will always remain matters of the greatest moment for the gold metallurgist. In fact, the modern gold metallurgist must be an all-round man, well trained in many fields; he must be a mining, mechanical and electrical engineer, a chemist and an electrochemist. With the steadily increasing use of electric power in metallurgical plants, it may be expected that electrochemical methods will find more and more favor with metallurgists because a highly effective agent for producing chemical action, in form of the electric current, is now readily available. On the other hand, the electrochemist who approaches the field of metallurgy must endeavor to become acquainted with those non-electrochemical methods and apparatus which he either has to use for a preliminary treatment or with which he has to compete. For this reason we believe our readers to be interested in the modern design of gold dredges to which we have already referred repeatedly in our columns.

The adjoining diagrams show a new gold dredge which is being brought out by A. W. Robinson, 14 Phillips Square, Montreal, Canada, especially for exploration purposes. It is designed to be a light and powerful dredge with sufficient strength and capacity to enable it to clean up bed rock at 22 feet depth and to handle free material at the rate of 60 tons per hour. Although very small and light, it is provided with all the motions of larger and more powerful machines, and its working parts are as few and simple as possible. It is built wholly of the best grade of steel and with no cast-iron entering into its construction whatever except such parts as cannot be made of any other material so well, such as the engine cylinders. The principle of the machine is simplicity itself. There are but two working shafts in the whole of the upper machinery driving the buckets and screen. These are mounted on a steel frame which is very strong and light and readily put together.

The dredge is erected and fitted up complete at works before shipment, and all principal parts of machinery tested in operation. The time, expense and labor of erecting and fitting up the dredge at its destination is thus reduced to a minimum, and the work required will only be that of putting the parts in their place, where they have been before. The arrangement of the parts is such that the various movements are accomplished with directness and simplicity, and so that all the operations are under the control of one man. For facility in shipment, all parts are made as light as possible, and subdivided into convenient sizes and weights.

The dredge is fitted with steel buckets having a nominal capacity of 1.5 cubic feet each. The material as excavated by the buckets is delivered into the hopper and passed through a revolving screen and washed therein. The coarse tailings from this screen are rejected and discharged by means of a gravity chute. The fine material contained therein passes through the screen into a long sluice box fitted with riffles, by means of which the gold is saved. The perforations in the screen are of such a size that about 20 per cent of the material is rejected and discharged over the side, and about 80 per cent passes through the sluice box, and is discharged astern.

The movements of the dredge are controlled by wire ropes attached to anchorages or on shore. For this purpose an independent steam winch is furnished having six drums.

The hull is of steel 72 feet long, 22 feet wide and 4 feet 6 inches deep; it is formed of two pontoons catamaran style. Each pontoon is 8 feet wide, and they are connected together by steel girders placed in suitable position. For convenience in shipment the hull is subdivided according to the conditions of the case. Where the locality can be reached by rail or wagon haulage, the hull is shipped in six sections, riveted up complete. Wherever necessary the hull is shipped in a knocked-down state, every piece being first fitted to position, so that the work of putting it together is reduced to a minimum.

The bucket chain is formed entirely of steel forgings and steel plates. The lip-plates of the bucket forming the cutting edge are of a special grade of hard and tough steel 8 inches wide and ⅝ inches thick. The pins are of manganese steel, and the pin joints are fitted with hardened steel bushings arranged to be renewable.

All the fittings and attachments of the dredging apparatus are of strong and light construction. The tumblers are of cast-steel, and the ladder frame itself is of steel.

A steel-plate hopper receives the discharge of the buckets and conducts it into the mouth of the screen. This hopper is made in sections attached to the main framing, and all parts subject to the wear of the material have renewable lining plates.

A cylindrical revolving screen, built of perforated steel

plates, is placed so as to receive the material from the hopper. It is set at an inclination of 1 to 12, and is of sufficient diameter to receive all the material that the buckets can deliver without choking. The screen is built with a steel frame having perforated plates attached to it in such a way that they can be readily renewed or replaced without taking the screen apart.

The upper tumbler is driven by a steel gear from a steel pinion on the countershaft. The main gear is 6 feet in diameter. The countershaft has a steel pinion on one end of it which engages with the main gear and a belt pulley 6 feet diameter by 14 inches face on the other end, and it is connected to the main engine by means of a belt. The belt thus furnishes a frictional medium for the transmission of power, so that the parts are relieved from sudden strain. The main and countershafts are carried in cast-steel bearings lined with babbit metal and securely bolted to the steel framing.

The screen is carried within a screen box formed of steel-plate and having suitable supports within it for the rollers upon which the screen will rest. The screen box also has the necessary pipe connections for the sluicing water, which is furnished by the centrifugal pump.

A steel plate stone chute is provided for carrying off the coarse tailings.

The main engines are of the vertical marine high-pressure type, of 32 indicated horse-power. They are built of special design to combine strength with lightness. All important bearing surfaces are extra large, adapted for continuous hard work, and complete provision is made for continuous lubrication. The engines have plain slide valves and turned steel column frames. The engines are fitted with a throttle valve and link motion, which is controlled from the operator's platform by levers and rods.

Water for sluicing purposes is supplied by an independent centrifugal pump having 8 inch suction and 6 inch discharge, placed upon the main deck, as indicated on drawings. The engines for driving this pump are of the vertical high-pressure type. The pump discharges part of its water into the head of the sluice box and part into the head of the screen, regulated as desired.

For the purpose of working the mooring lines and raising and lowering the bucket ladder an independent winch is furnished having six drums. Each drum will be fitted with independent clutch and brake for perfect control of the various motions. The winch is also fitted with a capstan head for general hauling and warping purposes. This winch is to be entirely of steel, no cast-iron being employed in its construction. The drums are of steel-plate with cast-steel heads and pressed-steel plate flanges. All the gears are of steel, and the frame is built up of steel plates and channels.

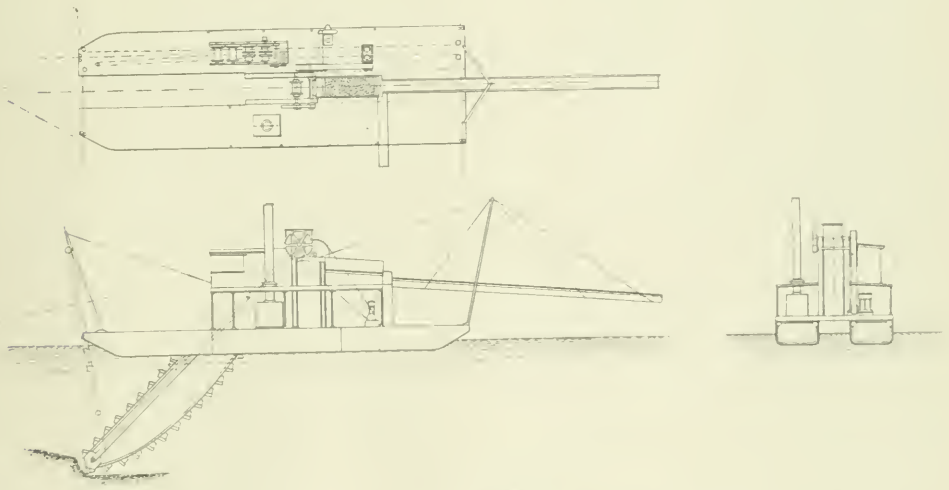
The two forward drums are provided with a powerful band-brake to each, the bands being made of steel lined with wood blocks. The standing part of the band is secured to the steel deck, and power is delivered to the bands by cross-shafts and levers connected with the operator's platform.

The four small drums are fitted with four standing brakes and provided with suitable adjustment.

The winch is driven by a pair of double reversible high-pressure engines having steel columns and frames similar in all respects to the main engines.

The movements of the dredge are controlled from the operator's platform on the upper deck on the starboard side directly over the winch. All lever connections for operating the winch are placed here in convenient position, and also levers for the main engines. In this manner the entire dredge can be operated by two men, not including those employed in fuel supply.

Steam will be furnished by one boiler of the water-tube type. This boiler will be specially built for the work and



GOLD DREDGE.

adapted to burn inferior wood and occupying small space and weight.

The bucket ladder is constructed from a steel frame by means of a warren truss of ample strength. The hauling part of the rope is carried to the winch as before described. The [illegible] is of sufficient capacity and fit to [illegible]

The [illegible] of the dredge, as indicated on the drawings, [illegible] steel and iron pontoons, the whole supported on a strong A-frame. The sluice box is fitted for its entire length with steel riffles of a size and character suited to the gold to be saved. The bottom of the screen box is also filled with riffles.

As will be seen, the dredge is manipulated entirely by wire-rope anchorages, no spuds being employed. A complete outfit for all purposes is furnished with the dredge of best quality of cast steel rope, galvanized to protect them from rust. This method of mooring enables the dredge to be used conveniently in almost any situation. It can work as well in an open river, with a current of six to eight miles per hour, as in an enclosed pond. It can dig its own flotation through dry ground above water level, and the sluice box is high enough to dispose of the tailings without the necessity of using a tailings elevator.

It is now recognized that the only really satisfactory way to test a gold-dredging property is by means of a dredge, and it is thought to be far better economy to begin with a small and light machine such as is here illustrated, which will furnish exact information as to the conditions to be met with, rather than to try experiments at the outset with a large and costly dredge, which may or may not be a success. This dredge is large enough to more than pay its working expenses if gold exists in the ground, and if the conditions are such as to warrant greater expenditures and larger machines they can then be entered upon with absolute assurance of success.

Mr. Robinson has been a dredge designer for twenty-five years, and has built more than 125 dredges of all types for all purposes, making a specialty of designing dredging machinery to suit the special conditions under which they have to work.

## HEATING AND VENTILATING EQUIPMENT FOR THE SHOPS AND OFFICES OF THE PENNSYLVANIA STEEL COMPANY, AT STEELTON, PENNSYLVANIA.

The Pennsylvania Steel Co. has recently erected at Steelton, Pa., a large shop and an office-building for its bridge and construction department. The system of heating and ventilating has been designed with much care, and exemplifies the latest practice in large, one-story structures.

For such buildings the fan and heater, or "hot-blast" system, is now considered to be the most suitable. In this system the steam piping is concentrated in a compact heater, which is enclosed by a steel housing. Due to the greater velocity of the air over the pipes of the heater, much less length of pipe is required than if the piping were scattered throughout the shop, and all dangers from freezing and bursting of pipes, setting fire to woodwork, etc., are of course eliminated. Air taken either from the shop or from out-of-doors is forced through the heater by a fan and is then carried to various points about the shop by a system of galvanized iron piping. The exhaust from the fan engine is condensed in a section of the heater arranged for that purpose, and there is, therefore, no loss of steam due to the engine.

The distribution of the heated air in the shop is a very important question and requires for its proper solution great care and long experience in this class of work. The hot air should be so delivered that there is no perceptible draft upon the workmen, but at the same time the outlets should be placed at short intervals apart and directed towards the floor, since that is where the heat is wanted. By this means it has been found possible, as in the works of the New York Shipbuilding Co., at Camden, N. J., to keep a zone of 9 or 10 feet in height comfortably warm, while the space overhead is in comparatively free communication with the outside air. This would be impossible with direct heating, or if the hot air were delivered through a few large outlets in the upper part of the building, as is sometimes practiced.

In the bridge and construction shops of the Pennsylvania Steel Co. there are 8 fan and heater equipments, consisting each of a steam-coil heater in connection with a steam engine-driven exhaust wheel. The heaters, with the remainder of the equipment, were furnished by the B. F. Sturtevant Co., and are built on that company's patent, corrugated cast-iron sectional bases, with 1-in. steam pipes set staggered and at the proper distance on centers to obtain the highest efficiency from the heating surfaces without restricting the passage of the air. The sections rest on heavy wrought-iron bases, with ample provision for contraction and expansion. The fans are enclosed in three-quarter, steel-plate housings, the lower part of the fan scroll being underground and forming a part of the foundation. They are driven by direct-connected, horizontal, side-crank engines. A system of galvanized iron pipe distributes the air throughout the buildings, the air being discharged through branch drop-connections having outlets near the floor. The ducts are of large size, with bends of long radius to reduce the frictional losses to a minimum. Each drop pipe is fitted with a butterfly damper, with a counter-weight for holding the same open or closed as may be desired. The entire apparatus is of sufficient capacity to heat the buildings to 65° F. in zero weather. In the case of the receiving shed, this applies only to a section 50 ft. in width in the middle of the building, but extending its whole length. Under the conditions of the contract the heater must take all the fresh air from out-of-doors. However, as the number of occupants in the building are few compared with the cubic contents, it will be found perfectly feasible and more economical to return a certain portion of the air from the buildings, and the apparatus is so arranged that this can be done. The apparatus is capable of changing the air in all the buildings every 25 minutes, and in the paint shops every 20 minutes.

The office building in connection with this department is heated by the same method, the apparatus being designed to furnish 21,430 cubic feet of air per minute, which is discharged into rooms having a total capacity of 289,763 cubic feet, thus providing for a complete change of air about every 15 minutes. The fan of the office-building heating-plant is not driven by a steam engine, as in the case of the sets furnished for the shop, but is direct-connected to a Sturtevant motor running at 200 revolutions per minute.

## INDUSTRIAL NOTES

Messrs. Fred. Berduch & Co., of New York City, sole agents for the *Deutsche Steinzeugwaarenfabrik für Canalisation und Chemische Industrie*, of Friedrichsfeld, Baden, Germany, have sent us the latter company's price list of stoneware vessels and apparatus for chemical, electrochemical and galvanoplastic industries. The catalogue is an exceptionally comprehensive and neat one and includes many colored plates, showing complete installations of salt cake and hydrochloric acid plants for the decomposition of about four tons of salt in twenty-four hours; Glover towers, intermediate towers and Gay-Lussac towers for sulphuric acid plants (Guttmann's ball tower being one of the most recent apparatus in this line); nitric acid condensing apparatus for the decomposition of 16 cwt. of nitre in twelve hours; denitrating plants; regenerating plants for use in smaller chemical works for nitrating operations; acetic acid rectifying apparatus; distillation apparatus for making acetic acid absolutely free from metals for medicinal purposes; Guttmann's reaction towers; Franz's condensing apparatus, condensing towers filled with Hoffman's cascade bands; distilling plants for fine chemical products; witherite and arsenic acid plants; stoneware pumps, exhaust fans, condensing vessels, etc. The company manufacture Dr. Buchner's patent material, which is a refractory and acid proof ceramic product; the porous diaphragms prepared from this material, although somewhat thicker than the ordinary ones, are said to offer excessively small resistance to the passage of the electric current, while they will prevent diffusion effectively. These diaphragms are also stated to be mechanically very durable. While the company manufacture plants for industrial operations on a large scale, they also make apparatus and vessels

for laboratory work and especially apparatus for electrolytic purposes in great variety.

Sparking Points for Automobiles.—We have received from Messrs. Baker & Co., of Newark, N. J., the eleventh edition of their "Data on Platinum" (see page 555 of this issue), also a list of the sizes of platinum rivets furnished by this company for use as contact points in telephones and other electrical apparatus, and a pamphlet with the title "Points for Automobilists." In the latter it is pointed out that the uninterrupted and efficient operation of automobiles propelled by hydro-carbon motors, depends to a large extent on the design and construction of the ignition device. To get an effective spark, it is necessary to get a good contact between the sparking points, and for this reason it is necessary to use points of a non-oxidizing and non-disintegrating material. As the sparking points are inserted within the combustion chamber of the engine, where there is a very high temperature, the points are very liable to disintegrate. Platinum has a high fusing point, does not oxidize, but is not hard enough for long service at high temperature. Messrs. Baker & Co. therefore supply now a special alloy for this purpose.

The Peterborough Hydraulic Power Co., of which Senator George A. Cox is president, is building a new power plant on the Otonabee River in the town of Peterborough, Ontario, Canada, which will be equipped with the following apparatus recently purchased from the Westinghouse Electric & Manufacturing Co.: A 1500-kw, 2240-volt alternator, running at 150 revolutions per minute, to be direct-connected to water-wheels; also two 125-volt exciters of 75-kw. capacity each, together with switchboard, consisting of a large generator panel and two exciter panels. This power house, when completed, will be an unusually fine one, and is to furnish power to the Peterborough Mill, of the American Cereal Co., owned by the Quaker Oats Co.; power will be supplied to several other manufacturing plants in the town, and also to the Peterborough Light & Power Co., which does the electric lighting and small power business in Peterborough.

Artificial Niagara at St. Louis.—An immense artificial cascade has been determined upon by the authorities of the Louisiana Purchase Exposition as the centerpiece of the semi-circular lay-out of the principal buildings. The cascade itself will be divided into three parts; a large middle cascade, with a smaller one at each side, the water flowing directly into the head of the Grand Basin. In all, about 90,000 gallons of water per minute will be supplied at a head of 150 feet, forming the greatest artificial water effect ever attempted.

The water will be taken from the Grand Basin itself and will be raised to the top of the cascade by a pumping station located under Festival Hall. The pumping machinery will consist of three 36-inch single-stage, turbine centrifugal pumps purchased from Henry R. Worthington, of New York city, each driven by a 2000-hp. Westinghouse alternating-current motor. The total horse-power utilized will thus be 6000, making this the largest electric pumping station in the world. The pumps and other pieces of machinery for this plant are now being installed at St. Louis.

## PERSONAL.

Dr. Hans Goldschmidt, of Essen Ruhr, Germany, the inventor of the thermit process, will visit this country in November, and is expected to deliver a lecture in Columbia University.

Dr Oskar Nagel has established an office and laboratory to act as a chemical engineer consulting chemist and chemical counsel in patent cases, at 90-96 Wall street, New York City.

Lieut. F. Tharaldsen, who has two large undeveloped water powers in Norway, of together 200,000 hp. is visiting this country with a view of studying the commercial development of electrochemical industries. His water powers being situated near the sea, he intends to utilize them for electrochemical plants.

## DIGEST OF U. S. PATENTS

Prior to July, 1902.

*Compiled by Byrnes & Townsend,*
*Patent Lawyers,*
*National Union Building, Washington, D. C.*

Dyes and Pigments. (Continued.)

323,514. August 4, 1885. W. Majert, Grunau, near Berlin, Germany.

Electrolyzes paramido derivatives of primary, secondary and tertiary aromatic amines, and hydrazo compounds of the latter, by dissolving them in water, acidulating, adding a substance which will evolve hydrogen sulphide and electrolyzing. Electrodes, platinum, platinized copper, silver, lead or carbon. May replace hydrogen sulphide by its persulphide, or by sulpho carbonic acid. May replace sulphuric acid by hydrochloric, adding ferrous chloride to neutralize chlorine and chloric and perchloric acids. For example, produces methylene-blue, by dissolving one part of paramido-dimethylaniline in forty parts of water, adding four parts of 66° Baumé sulphuric acid and some sodium sulphide solution, and electrolyzing. Blows air through the electrolyte to remove the residual hydrogen sulphide. The dye is precipitated from the electrolyte by zinc or sodium chloride. The cell is a wooden vessel lined with varnish. A vertical, wooden shaft with radial stirring arms rotates in the vessel. The electrodes are fixed to opposite sides of the vessel, and extend horizontally between the rotating arms, which carry brushes to clean the electrodes. May use a cell with a vertical diaphragm of earthenware, wood or parchment paper, or of earthenware plates set in a wooden framework. Fills one chamber with a sulphuric acid solution of paramido-dimethylaniline, containing sodium sulphide, and the other chamber with a sulphuric acid solution of nitroso-dimethylaniline. Each chamber contains a rotary stirrer, the adjacent arms of one stirrer carrying brushes to clean the anode, and those of the other stirrer, brushes to clean the cathode. This apparatus serves not only to produce methylene-blue, but simultaneously produces from the nitroso-dimethylaniline the paramido dimethylaniline required for the production of the methylene-blue, the current being reversed through the cell. The anode and cathode compartments may be connected by a bent pipe, instead of using a diaphragm.

477,735. June 28, 1892. J. Blair, Spokane, Wash.

Produces a basic lead sulphate by electrolyzing a solution of sulphuric acid ten parts, sodium or potassium nitrate five parts, and water twelve parts, between vertical lead anodes and carbon cathodes, which line the sides of the cell. Injects steam to heat the electrolyte. The lead is converted into a white powder consisting of sulphate mixed with some nitrate. This powder is washed with a dilute caustic soda solution, to convert the lead nitrate into hydrate. The wash liquor is evaporated and fused with charcoal to reproduce caustic soda.

538,968. May 7, 1895. A. B. Browne, Cambridge, and F. D. Chaplin, Natick, Mass.

To produce lead chromate, first produces a solution of lead nitrate, acetate or chloride in a diaphragm cell with lead electrodes and an electrolyte of an alkali nitrate, acetate or chloride. The caustic alkali overflows from the cathode compartment. Another solution of chrome hydrate is simultaneously prepared by precipitating a solution of chrome alum with caustic alkali, filtering, washing and redissolving in an excess of caustic alkali. The resulting solution is mixed with a solution of sodium chloride and electrolyzed, giving a variable mixture of potassium bichromate and chromate, which is mixed with the lead nitrate, acetate or chloride from the electrolytic cell. The precipitated lead chromate is filtered and washed. The color of the pigment can be varied by varying the relative amounts of the two chromates, which is a function of the time of electrolysis.

554,718. February 18, 1896. Ralph McKenzie, Jersey City, N. J.

Produces lakes or insoluble pigments by dissolving or suspending "the fundamental bases of coloring matters," such as chromic acid, alizarine or cochineal in an electrolyte and passing a current between electrodes of aluminium, tin or other oxidizable metal or alloy. Potential difference, 10 volts. To produce a brilliant red, dissolves aniline in water and electrolyzes with aluminium anodes, producing a "coagulated compound of insoluble hydrated aluminium and aniline."

557,324. March 31, 1896. G. D Burton, Boston, Mass.

Dyes wool, cotton, silk, fabrics, furs and leather in an electrolyte containing dye stuffs and between electrodes of copper, zinc, lead or other metal. Non-conducting screens may be placed in front of each electrode to prevent contact with the material. Some "benefit" is derived from copper electrodes. Cloth to be dyed may be run through the electrolyte. The electric current is said to separate the fibers of the material and cause rapid absorption of the dye. Examples: Water 30 gallons, salt 30 pounds, vitriol 12 ounces and a coloring matter. Specific gravity to be 1.000° to 1.025°. Current, 60 amperes at 500 volts, raising the temperature of the bath to 210° F. For a tank 6 feet by 3 feet by 1 foot deep, uses a current of 100 amperes at 220 volts. May also use a current of 400 amperes at 6 volts. For wool, dissolves 2 pounds of vitriol and 1½ pounds of "Fast Black, 3 B," in 20 gallons of water. Specific gravity, 1.030° to 1.037°. Current 55 to 70 amperes at 220 volts, which raises the electrolyte to the boiling point. To dye hats, blue-black, dissolves 3 ounces of "Hatter's Concentrated Black," 8 ounces of Glauber salt and ¾ ounce of oil of vitriol in 15 gallons of water; for a jet black, adds ½ ounce of "Green B." For an orange color, dissolves 20 ounces of Glauber salt, ¾ ounce of oil of vitriol and 4 ounces of acid-orange in 15 gallons of water. Current, 60 amperes at 220 volts. For a nutria color, dissolves 8 ounces of alizarin-brown in 15 gallons of water. For leather, uses a low current at high voltage.

557,325. March 31, 1896. G. D. Burton, Boston, Mass.

Similar to preceding patent, except both electrodes are of carbon.

557,326. March 31, 1896. G. D Burton, Boston, Mass.

Apparatus for dyeing and shrinking fabrics. Cell, earthenware lined with porcelain. Porcelain guide rolls in the cell. Anode, carbon; cathode, lead. Fabric may pass twice through the electrolyte. To dye brown and black, first heats the liquor by an electric current, between electrodes of lead, one of which is then replaced by carbon. Sixty amperes at 220 volts heats 20 gallons to the boiling point in ten minutes. Electrolyte for a peacock blue, water 20 gallons, Prussian blue 1½ ounces, citric acid 2 ounces, Glauber salt 1½ pounds, and sulphuric acid 1½ ounces. Specific gravity, 1.125°. Current, 60 to 100 amperes at 120 to 220 volts.

588,883. August 24, 1897. P. G. Salon, Philadelphia, Pa.

To produce litharge, first electrolytically reduces lead ore to sponge. Places crushed galena in a porous cup with a lead cathode, and surrounds the cup with dilute sulphuric acid containing a lead anode. The electrolytic hydrogen converts the lead into a sponge, which is washed, dried and heated, first at a temperature below the melting point of lead and then at a bright red, being thereby converted into litharge.

602,873. April 26, 1898. J. W. Richards and C. W. Roepper, Bethlehem, Pa.

Produces all metallic sulphides except those which are soluble in the electrolyte, by electrolyzing a solution of sodium or other soluble thiosulphate, preferably of 10 per cent strength, with an anode of the metal whose sulphide is desired, and a carbon cathode. Mixed sulphides may be produced by using an alloy anode. The precipitated sulphide is removed from the bottom of the cell, filtered, washed, dried and pulverized. For cadmium sulphide, preferably adds 5 per cent of sodium chloride to the electrolyte, and heats it to 75° C. For antimony sulphide, uses a cold solution.

626,330. June 6, 1899. Carl Luckow, Cologne-Deutz, Germany.

Produces lead peroxide, by electrolyzing a 0.3 to 3 per cent aqueous solution of a mixture of sodium, potassium or amonium sulphate, 99.5 per cent, and sodium potassium or amonium chlorate 0.5 per cent, between lead electrodes. Current, 50 amperes at 3 volts. Current density 0.5 amperes per square decimeter. Air is injected during the process.

626,331. June 6, 1899. Carl Luckow, Cologne-Deutz, Germany.

Produces neutral lead chromate by electrolyzing a 0.3 to 3 per cent aqueous solution of sodium, potassium or ammonium chlorate, 80 per cent, and sodium potassium or ammonium chromate, 20 per cent, between electrodes of lead, the anode preferably of soft lead, and the cathode of antimonal lead. Current, 50 amperes at 1.8 volts; density at anode, 0.5 amperes per square decimeter. Electrolyte kept neutral and water and chromic acid continuously added during the electrolysis.

626,547. June 6, 1899. Carl Luckow, Cologne-Deutz, Germany.

Produces copper oxide by electrolyzing a 0.3 to 3 per cent aqueous solution of sodium, potassium or ammonium borate, 95 per cent, and sodium, potassium or ammonium chlorate, 5 per cent, between electrodes of copper. Current, 50 amperes at 2 volts; density, 0.5 amperes per square decimeter. Air is injected during the process.

627,266. June 20, 1899. Carl Luckow, Cologne-Deutz, Germany.

Produces acid lead chromate by electrolyzing a 0.3 to 3 per cent aqueous solution of sodium, potassium or ammonium chlorate, 80 per cent, and sodium, potassium or ammonium chromate, 20 per cent, between electrodes of lead, the anode preferably of soft lead and the cathode of antimonal lead. The electrolyte is kept faintly acid and chromic acid and water are continuously added as consumed. Current, 50 amperes at 1.5 volts; density at anode, 0.5 amperes per square decimeter.

627,267. June 20, 1899. Carl Luckow, Cologne-Deutz, Germany.

Produces basic copper phosphate by electrolyzing a 0.3 to 3 per cent aqueous solution of sodium, potassium or ammonium chlorate, 80 per cent, and sodium, potassium or ammonium phosphate, 20 per cent, between electrodes of copper. Continuously adds phosphoric acid and water, as consumed. Current, 50 amperes, at 2 volts; density at anode, 0.5 amperes per square decimeter.

666,262. January 22, 1901. C. G. Collins, New York.

Produces a composite pigment by electrolyzing an aqueous solution of salt from which barium sulphate may be precipitated, for example the dithionate, and a vegetable or coal tar color, such as an anilin salt capable of electrolytic dissociation. The ions of the anilin salt recombine in the presence of the finely divided barium sulphate precipitate, and the pigment falls to the bottom of the cell. The barium salt and dye may be added as required.

666,302. January 22, 1901. C. G. Collins, New York.

Produces a composite pigment by precipitating finely divided hydrated silica in the presence of a soluble dye, with an insoluble anode. For example, electrolyzes an aqueous solution of sodium silicate and eosin red (potassium tetra-bromo-fluorescein), replenishing the silicate and dye as required.

670,201. March 19, 1901. E. D. Kendall, Brooklyn, N. Y.

Produces precipitated zinc oxide and nitrites by electrolyzing an aqueous nitrate solution, for example, sodium nitrate, between an anode of zinc and a cathode of carbon, copper, iron, tin-plate or lead. May use a tank of wood or one of iron serving as the cathode. Potential difference, 6 volts or less, but preferably more. A tray may rest on the bottom of the tank to receive the zinc oxide.

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### THE INDEX TO OUR FIRST VOLUME.

Once in each year the editor of a technical journal is permitted to publish an advertisement for his journal—the index accompanying the last issue of the volume. If the editor is inclined to statistics or statistical tricks, he may supplement the dry columns of names and titles by a bewildering array of figures, to prove to even the most incredulous reader that his journal is the only perfect one of its kind. Since the writer's talent for statistical fireworks is small, he may be permitted to say a few words concerning some questions which came up in the preparation of the index. If, besides fulfilling the useful purpose of an editorial advertisement, an index be good for anything, everybody of ordinary intelligence must be enabled to find with its aid the information which he looks for, if it is contained in the volume. Too much valuable information is buried forever in excellent periodicals simply on account of defective indexes. We are far from believing that our index is perfection, but we may say that we have tried at least to prepare it with the greatest possible care. We have endeavored to classify the subjects as much as possible. For instance, all mercury cathode processes for electrolyzing sodium chloride are collected together, whatever the title of the article may be in which the information appears. This principle is followed where it was possible. In the case of storage batteries, where such a classification would have been highly desirable it was found to be impossible, and was given up as a bad job. Whenever an article on a certain subject contains incidentally valuable information on another subject, the index should show it. Whenever new terms are proposed by an author, they are given in the index, so that if they should be used later without explanation, the reader may find their definition. Cross references have been given wherever it seemed advisable. While it would be the best thing to have always in mind all the information on a certain subject, the next best thing is to know how and where to find this information, and we hope that our index will be helpful to our readers in this direction.

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### ELECTROLYTIC COPPER REFINING.

Electric copper refining is that branch of electrometallurgy which without doubt has achieved the greatest commercial importance. The yearly output of the electrolytic refineries of this country alone is now estimated at 280,000 tons of copper. The importance which this industry has attained is mainly due to the excellence of the product. To measure the degree of purity of copper, we still use Matthiessen's old standard of electrical conductivity, although the figures for the purity of the commercial copper of to-day, based on this standard, have a very significant appearance, being often above 100 per cent. To quote a remark of Mr. Addicks in a paper

printed in this issue, the fact that the quality of the copper on the market to-day often exceeds by as much as 1 per cent the purest laboratory copper of forty years ago, forms an interesting commentary on the excellence of modern industrial methods.

One point which characterizes the modern American methods of copper refining is the high degree of mechanical development, of skillful arrangement of the whole plant, and the extensive use of labor-saving devices. It will be remembered how enthusiastically this point was emphasized by Prof. Haber in his report on electrochemistry in the United States, when discussing the Anaconda refinery. This high mechanical development has been of great influence upon the development of the refining industry in this country, for a consequence has been to concentrate the industry in not more than ten large plants. The reason for this situation is that smaller plants cannot compete with our larger plants, since for a small plant it would not pay to provide the highly developed mechanical equipment of the larger works.

On the other hand, it would be incorrect to assume that the excellence of the mechanical equipment alone explains the success of our copper refining industry. Hand in hand with the installation of improved machinery and apparatus, the engineers of the refineries of this country have carried on extensive investigations in the electrochemical side of the problem, although naturally very little has been published of the results thus obtained. The rule of thumb has long ago ceased to rule in our large refineries, and careful scientific investigation has been substituted for it. True, the modern theories of electrochemical science—and especially the electrolytic dissociation theory—may be said to have had little or no influence on these investigations and on the development of copper refining in general. Yet these investigations were made in a truly scientific spirit, and by modern scientific methods.

Like any engineering problem, the problem of the electrochemist of an electrolytic refinery is essentially a financial one, namely, if the conditions of operation are varied in all possible directions, under which conditions will the cost be a minimum? Considered from this point of view, which is the proper one for an engineer, the problem of the best conditions of the method of refining copper—which, from a purely scientific point of view, might be considered, perhaps, the simplest process in the whole of electrochemistry—appears quite complicated. There are a great many details to be considered, and the different factors which determine the final cost are so inter-related that it is very dangerous to arrive at conclusions concerning the final cost by taking into account only some factors and neglecting others.

Nevertheless, the only way by which research in this line can proceed, is to study each determining factor separately, to study the change of the conditions if this one determining factor alone is varied, while all others are kept constant, and to take up in this way all determining factors, one after the other. In this way Prof. Bancroft's recent investigation gives valuable information on the cost as function of current density and temperature. As to Prof. Bancroft's conclusions, it is a fact that among engineers of refineries there is a very emphatic disinclination as regards covered tanks, so that a higher temperature than used as present is considered impracticable. On the other hand, we know of at least one large refinery which studied the problem of the most economical current density and temperature some years ago in a way similar to that of Dr. Bancroft, and we have reasons to assume that nearly all of our large refineries have made extended researches in this direction in the past. It may, therefore, be assumed that the current density used by the various refineries has been adopted as the one which, in the opinion of those in daily touch with the conditions, is the most economical one in each case. If this be true, then the fact that there is such a great difference between the current densities used by the different refineries, can only be explained by the assumption that the current density is so inter-related with the other factors which determine the final cost that in the different cases of the various refineries the cost becomes a minimum for considerably different current densities, because the other conditions are considerably different.

A detail of copper refining, though a very interesting one, is discussed in the admirable article of Mr. Benjamin Magnus, published in this issue, on contact resistances and current leakages in an electrolytic copper refinery. When our readers have analyzed the figures given in the article, they will appreciate the importance of this detail for every refinery, and, in fact, for every electrolytic plant, and we join the author in the hope that his article will stimulate some exhaustive experimenting by electrolytic refiners and others along the lines of contact resistances. Mr. Lawrence Addick's paper, also published in this issue, is particularly valuable on account of the exact information given in the diagrams on the influence of impurities in commercial copper and of the method of mechanical treatment upon its electrical conductivity.

## ELECTRIC ENDOSMOSIS AND PEAT BOG.

When an electric current passes through an electric cell, concentration differences at the two electrodes are observed which are due to the different mobilities of the anions and cations, together with the effect necessarily combined with the electrochemical action at the electrodes. For instance, if we electrolyze copper sulphate between two copper plates, copper ions pass out of the electrolyte to the cathode and copper ions are introduced into the electrolyte from the anode; besides this there is a change of concentrations due to the different mobilities of the Cu and $SO_4$ ions. If a porous diaphragm were introduced between the anode and cathode—which, of course, would not fulfill any technical purpose—another phenomenon would be added to the concentration changes which are produced without diaphragms. This other phenomenon is commonly called electric endosmosis or cataphoresis, and consists in a bodily transfer of the electrolyte from one side of the diaphragm to the other. Some time ago we referred in these columns to a suggestive paper of Prof. Bancroft, read at the New York meeting of the American Electrochemical Society, in which he pointed out that it would be absolutely incorrect to neglect the effect of electric endosmosis in diaphragm cells, since its value may be very consid-

erable. He also pointed out that the material from which the porous diaphragm is made is of decisive importance, and that it would be incorrect to consider the diaphragm as inert. In view of the extensive use to which porous diaphragms are put in various commercial electrochemical cells, the problem should invite careful attention, not only from scientists, but from electrochemical engineers.

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With a stationary diaphragm the phenomenon of electric endosmosis consists in the bodily transfer of the liquid from one side to the other. But this is not the proper way to describe the phenomenon in its most general form. The phenomenon consists in a relative bodily motion of the liquid against the diaphragm. If the diaphragm is stationary, the liquid moves, but if the diaphragm is movable it will move in a direction opposite to that of the liquid in the other case. The case of a movable diaphragm is not a purely theoretical conception; on the contrary, it is very often met with in practice. Slimes or solid pastes filled with a liquid represent movable diaphragms. It should therefore be possible to apply electric endosmosis to a separation of the solid particles from the liquid. That this conclusion is correct, is, in fact, shown by the experiments described in a paper read by Count Schwerin before the International Congress for Applied Chemistry, an abstract of which will be found in this issue.

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The most interesting experiment of Count Schwerin is the application of electric endosmosis to the removal of water from peat bog. The latter problem is an extremely important one. Many countries, for instance, Ireland, are rich of peat bog, at present practically worthless, but which would represent a great increase of the national wealth if a practical method were found for removing the water from the peat. On account of capillary action, settling does not take place, and evaporation of the water would be far too expensive. A long series of processes have been proposed for the solution of this problem, but none has thus far been successful. We do not find anything in Count Schwerin's paper which would prove that the application of electric endosmosis really means the commercial solution of this problem, but we may emphasize that here a new method has been proposed, based on correct principles. The proposed application shows at least that the phenomenon of electric endosmosis is not merely a subject for scientific investigation, but might become of considerable importance for industrial purposes.

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The experiment of Count Schwerin is very simple. Peat bog, containing 85 to 90 per cent of water, is placed into a perforated wire basket which serves as cathode. The anode is suspended in the peat bog. As long as the circuit is not closed, the peat does not lose any of its water, because it is held in its pores by capillary action; but when the current is turned on, the water begins to percolate through the wire basket. It is not stated that it is possible to remove all the water from the peat, nor are any data given concerning the financial side of the process. We may call attention to a possibility which should interest metallurgists, that this process might be commercially applied to the removal of water from slimes, which is often desirable in chemical or electrochemical work. The subject is certainly interesting and important enough to invite further study.

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## ELECTROLYTIC PRODUCTION OF COMPOUNDS

The Digest of United States patents prior to July, 1902, has already considered the patented art relating to certain standard applications of electrochemistry to industry. In the manufacture of caustic alkalies and chlorin, of chlorates and bleaching liquors, electrolysis holds, or is acquiring a dominating position, and in other lines, as the production of white lead and other pigments, it has capabilities which will attain equal recognition when the essential conditions for even and continuous work are known; for in these lines the peculiar advantages of the electrolytic procedure, the simplicity and certainty of operation, and the nice capability for adjustment of conditions, are of especial importance. Aside from these standard lines, there has passed the Patent Office an electrochemical miscellany—a series of patents whose chief present value lies in their suggestiveness, and the conception which their perusal gives as to the real breadth of the electrochemical field. The first installation of these patents is abstracted in the current issue.

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## CARBON CELLS.

The Synopsis of this issue gives abstracts of two articles on carbon cells, one by Prof. Lorenz, and another by Mr. Jone. It is well known that the present method of generating electrical energy from carbon by means of steam engine and dynamo is an extremely roundabout method, and necessarily of very low efficiency. For many years the production of electrical energy direct from carbon in a carbon cell has been the dream of electrochemical inventors. The idea in general has been to devise a cell in which the electrochemical reaction should consist essentially in the oxidation of carbon, just as the electrical energy of the Daniell cell comes from the change of zinc into sulphate. If all the chemical energy in the cell could be completely changed into electrical energy, the efficiency would be 100 per cent. The dream is so beautiful and the scheme is so simple, that it is a pity we are obliged to state squarely and fairly that we are now just as far from its realization as ten years ago.

There is, however, another method for changing the chemical energy of the oxidation of carbon into electrical energy. The scheme is to use an ordinary primary cell, and to regenerate the materials which have undergone a change during discharge to their original condition by means of carbon. The total change of materials in a complete cycle, representing discharge and regeneration, should consist in the loss of carbon which has combined with oxygen from the air. For instance, in the Daniell cell the scheme would be to reduce the zinc sulphate of the discharged cell back to zinc by means of carbon. An application of this principle is the cell devised by Jone and described in the Synopsis which, however, is identical with the cell which for some time was exploited sensationally in the newspaper press. While we at present refrain from any criticism of this special cell, we may say that attempts in this general direction seem more promising than the invention of what might be properly called a carbon cell.

## THE OUTCOME OF THE ALUMINIUM LITIGATION.

In our last issue we published an abstract of the recent decision in the suit of the Electric Smelting & Aluminum Co. versus the Pittsburgh Reduction Co. over the Bradley patent. From a correspondent, who is not connected with either company, we received the following information:

"The Pittsburgh Reduction Co. and the Electric Smelting & Aluminum Co. have reached a friendly agreement on the Bradley patent, to the effect that the Pittsburgh Reduction Co. has paid damages to the Electric Smelting & Aluminum Co. for the aluminium made by the former company up to the present, and will work under license of the Electric Smelting & Aluminum Co. in future. There shall be no more litigation between the two companies, and the Pittsburgh Reduction Co. shall have the monopoly for the production of aluminium until 1909."

In order to confirm this information we wrote to the Pittsburgh Reduction Co. and the Electric Smelting & Aluminum Co., asking whether this information is correct, and received from Mr. Alfred H. Cowles, president of the Electric Smelting & Aluminum Co., the following reply:

"The information is entirely correct. The settlement also involves the Cowles Electric Smelting & Aluminum Co. at Lockport, continuing to deal in all grades of aluminium under conditions where they will be able to supply the market at very favorable terms. The license extended to the Pittsburgh Reduction Co., under which they will pay royalty, reaches only to the manufacture of aluminium and aluminium alloys, and not to other uses to which the Bradley and Cowles patented processes are adapted. The Electric Smelting & Aluminum Co., owning the Bradley patents, stand ready to encourage electric smelting on lines where these patents are applicable, and to grant licenses on favorable terms for specific uses wherever the protection of the Bradley patents may be of value to newly developing industries."

## INTERNATIONAL ELECTRIC CONGRESS.

The preliminary programme of the International Electrical Congress, to be held at St. Louis from September 12th to 17th, 1904, has just been issued. The date set for the Congress is the week, 12th to 17th September, 1904. This is the week preceding the session of the great scientific congress appointed by the Universal Exposition. On this account many of those who attend the International Electrical Congress will probably remain to attend the International Congress of the Arts and Sciences.

In accordance with the present plan, members arriving via New York will be enabled to reach St. Louis via Niagara Falls on Sunday, September 11th. Members will also be invited to attend the dedication ceremonies of the National Bureau of Standards at Washington. It is hoped that arrangements may be completed whereby the President of the United States may then meet the members.

On the morning of September 12th, at 11 a. m., a general convocation of the International Electrical Congress will be called. On the four succeeding days, from the 13th to the 16th, inclusive, meetings of the eight sections of the Congress will be held simultaneously. On the final day, September 17th, a second general convocation will be called. Members returning from St. Louis to New York may elect to stop off at Chicago and at Niagara Falls.

As at present proposed, the International Electrical Congress will comprise three distinct features:

First—A Chamber of Delegates, appointed by the various governments, and essentially similar to the Chambers of Government Delegates at the International Electrical Congresses of Chicago in 1893, and of Paris in 1900. It would seem that sufficient material has been collected since 1900, calling for international action, to warrant inviting the various governments to appoint delegates, as before, to the International Electrical Congress at St. Louis.

Second—The main body of the Congress, divided into eight sections. These sections, together with the names of the officers, appointed by Prof. Elihu Thomson, president of the Committee of Organization of the Congress, are given in the following table:

| Section. | | Subject. | Chairman. | Secretary. |
|---|---|---|---|---|
| A | | General Theory; Mathematical and Experimental | Dr. E. L. Nichols, Cornell Univ. | Dr. H. T. Barnes, McGill Univ. |
| B | | General Applications | Dr. C. P. Steinmetz | Dr. S. Sheldan, Schenectady, N. Y. |
| C | | *Electrochemistry* | Dr. H. S. Carhart, Univ. of Mich. | Poly. Inst., B'klyn Mr. Carl Hering, Philadelphia |
| D | Applications. | Electric Power Transmission | Mr. Chas. F. Scott, Pittsburg. | Dr. Louis Bell, Boston. |
| E | | Electric Light and Distribution | Mr. J. W. Lieb, Jr., New York. | Mr Gano S. Dunn, Ampere, N. J. |
| F | | Electric Transportation | Dr. Louis Duncan, Mass. Inst. Tech. | Mr. A. H. Armstrong Schenectady. |
| G | | Electric Communication | Mr. F. W. Jones, New York | Mr. B. Gherardi, Jr New York. |
| H | | Electrotherapeutics | Dr. W. J. Morton, New York. | Mr. W. J. Jenks, New York. |

Third—Conventions simultaneously held, in connection with the Congress, by various electrical organizations in the United States. It is proposed that each section of the Congress may be able to hold its meeting under some plan of conjunction with the organization or organizations devoted to the progress of the work selected by that section. Steps have already been taken to enlist the sympathy of the various organizations, with a view to perfecting the details of co-operation at a later date. Prominent among the organizations from whom co-operation is expected are: The American Institute of Electrical Engineers, The American Electrochemical Society, The National Electric Light Association, The Association of Edison Illuminating Companies, The Pacific Coast Transmission Association, and The American Electrotherapeutic Association. It is also hoped to secure the participation of American scientific societies.

The Universal Exposition at St. Louis has signified its intention of affording ample facilities for the accommodation of the Congress in its halls on the grounds of the Exposition.

The Committee of Organization of the Congress is as follows: President, Elihu Thomson; vice-presidents, B. J. Arnold, H. S. Carhart, W. E. Goldsborough, C. F. Scott, S. W. Stratton; general secretary, A. E. Kennelly; treasurer, W. D. Weaver.

The Advisory Committee consists of Messrs. B. A. Behrend, C. S. Bradley, J. J. Carty, A. H. Cowles, F. B. Crocker, Louis Duncan, H. L. Doherty, R. A. Fessenden, W. J. Hammer, Carl Hering, C. P. Matthews, R. D. Mershon, K. B. Miller, W. J. Morton, E. L. Nichols, R. B. Owens, F. A. C. Perrine, M. I. Pupin, J. W. Richards, H. J. Ryan, William Stanley, C. P. Steinmetz, L. B. Stillwell, J. G. White and A. J. Wurtz.

The plans of the Committee of Organization are to invite all interested in electricity and its applications to accept membership in, and to attend the Congress, if possible; to convene the Congress during the week set aside by the Universal Exposition for that purpose (12th to 17th, September); to report the meetings of the Congress, and to publish the Transactions subsequently, each member of the Congress to receive a complete copy thereof. The fee for membership has been fixed at $5, the proceeds to be expended in stenographic and other expenses, incident to the conduct of the Congress, and in printing the Transactions. Applications for membership are to be sent to the general secretary, Dr. A. E. Kennelly, Harvard University, Cambridge, Mass.

Aluminothermics.—Dr. Hans Goldschmidt, whose experimental lecture before the Chemical Society of Columbia University is reported on another page, will deliver another lecture before the American Society of Mechanical Engineers on December 3.

## CONTACT RESISTANCES AND CURRENT LEAKAGES IN AN ELECTROLYTIC COPPER REFINERY

By BENJAMIN MAGNUS.

During the course of some experiments the object of which was to determine the additional cost of depositing a ton of copper due to the power lost in contact resistances, we derived the results given below, which I take great pleasure in presenting to the readers of ELECTROCHEMICAL INDUSTRY, with the hope that these figures will stimulate some exhaustive experimenting by electrolytic refiners and others along the lines of contact resistances.

Following are the results obtained on a tank which had mercury wells for all electrode contacts.

CONTACT RESISTANCES—MERCURY CONTACTS.

| Date. | Current. | Tank Voltage. | Anode to Bus-Bar | Cathode to Bus-Bar. | Anode to Cathode. | Anode Contact. | Cathode Contact. | Cathode Hanger & Bus-Bar. | Anode Hanger & Bus-Bar. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-1 | 4000 | 0.198 | 0.011 | 0.036 | 0.150 | 0.003 | 0.008 | 0.010 | 0.004 | No. 1 | Remark. |
| 4-7 | 4000 | 0.180 | 0.007 | 0.030 | 0.130 | 0.004 | 0.006 | 0.005 | 0.003 | " 2 | " |
| 4-12 | 4000 | 0.194 | 0.013 | 0.024 | 0.157 | 0.005 | 0.005 | 0.004 | 0.003 | " 3 | " |
| 4-18 | 4000 | 0.185 | 0.014 | 0.020 | 0.150 | 0.005 | 0.004 | 0.002 | 0.003 | | |
| 4-23 | 4000 | 0.167 | 0.013 | 0.018 | 0.134 | 0.007 | 0.005 | 0.002 | 0.015 | " 4 | " |
| 5-2 | 4000 | 0.190 | 0.028 | 0.014 | 0.148 | 0.005 | 0.005 | 0.002 | 0.019 | | |
| 5-7 | 4000 | 0.261 | 0.038 | 0.014 | 0.176 | 0.006 | 0.003 | 0.002 | 0.028 | " 5 | " |
| Av. | 4000 | 0.197 | 0.018 | 0.022 | 0.150 | 0.005 | 0.005 | 0.004 | 0.009 | | |

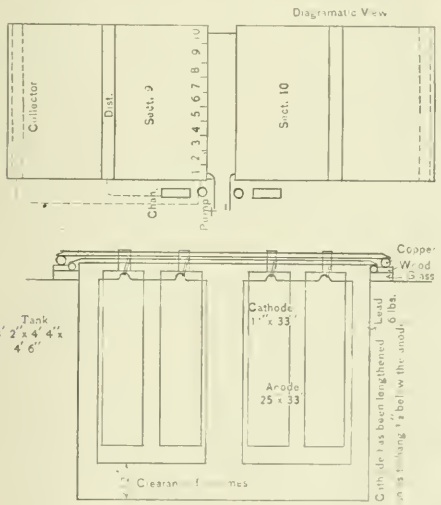



FIG. 1.—DIAGRAMATIC VIEW OF SUSPENDED ANODE AND CATHODE.

The average current density was 11 amperes per square foot.

The average temperature of electrolyte was 98° F.

No. 1. Remark—Before thin starting sheets were straightened.

No. 2. Remark—Serious short circuiting of tanks; ampere efficiency only 88 per cent.

No. 3. Remark—Starting sheets straightened.

No. 4. Tank slightly grounded, total voltage low but contacts higher.

No. 5. Remark—Just before pulling, current density in anode about twice as high as at start of deposition.

These figures show what a low tank voltage it is possible to get, and when we add to the "Effective Voltage" (0.150) 0.007 volt due to drop across the slimes on surface of anode, we have 79.7 per cent of our energy effective in deposition work which will be noticed as an improvement over the results obtained on a regular tank. But mercury contacts are impracticable.

Figure No. 1 shows a diagrammatic view of the suspended anode and cathode.

The anode is suspended by copper hooks from a copper-covered iron bar, which is the positive supporting bar. This bar rests on a positive bus-bar at each end.

The cathode is suspended by a copper hanger (fastened with a tinner's machine) from the negative supporting bar which has bus-bar contacts similar to the anode supporting bar.

Following the path of the current from the time it enters the positive supporting bar until it reaches the negative bus-bar we find the following contact resistances:

FIG. 2.—GENERAL VIEW OF ELECTROLYTIC REFINERY, SILVER MILL, POWER PLANTS AND CASTING PLANTS.

| | |
|---|---|
| Current (amperes) | 4000 |
| Voltage per tank | 0.230 |
| Current density (ampere per square foot) | 11 |
| Energy in K. W. | 0.920 |
| | Volts. |
| Drop between the anode rod and the bus-bar. | 0.0270 |
| Drop between the cathode rod and the bus-bar. | 0.0135 |
| Drop between anode rod and anode hanger. | 0.0060 |
| Drop between cathode rod and cathode hanger | 0.0045 |
| Drop between anode hook and anode | 0.0008 |
| Total losses | 0.0518 |
| Per cent total energy lost in contacts | 22.5 |

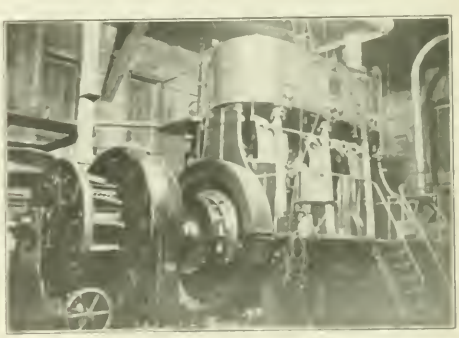


FIG. 3.—VIEW OF TRIPLE EXPANSION ENGINE COUPLED TO DYNAMO, BUILT FOR 3,600 AMPERES, BUT RUN CONTINUOUSLY FOR THREE YEARS AT 4,000 AMPERES

These voltages are the averages of many readings. They vary according to the condition of the tank

Below are the variations in ampere efficiency; in this case the value of the contact resistance is inversely proportional to the ampere efficiency. (This is not absolutely a condition which always exists).

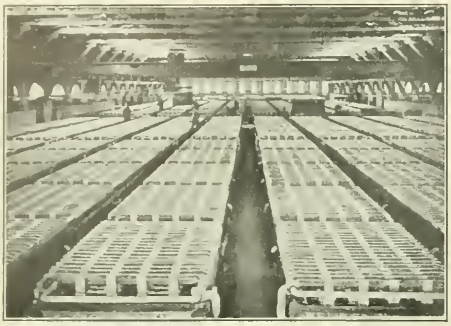


FIG. 4. VIEW OF TANK HOUSE, EACH TANK PRODUCING 7,000 LBS. OF Cu PER MONTH.

DAILY INCREASE IN POUNDS AT BEGINNING AND END OF DEPOSITION.

Current Constant at 4000 amperes.

Average ampere efficiency of tank, 91.5 per cent.

BEGINNING.

| | Weight. | Gain | % Amp. Efficiency. | % Total Energy Lost in Contacts. |
|---|---|---|---|---|
| April 10..... | 1025 | | | |
| Apirl 11..... | 1225 | 200 | 80.3 | 24.3 |
| Apirl 12..... | 1435 | 210 | 84.3 | 23.8 |
| April 13..... | 1655 | 220 | 88.3 | 23.3 |
| | ENDING. | | | |
| May 14..... | 6728 | | | |
| May 15..... | 6945 | 217 | 87.1 | 23.2 |
| May 16..... | 7140 | 195 | 78.3* | 25.0 |
| May 17..... | 7345 | 205 | 82.5 | 24.0 |
| May 18..... | 7549 | 204 | 81.9 | 24.0 |
| May 19..... | 7750 | 201 | 80.7 | 24.9 |

*Scrapped this day.

When the tank is first loaded, the cathode contacts have great resistance, but improve when the cathode acquires weight. The anode contacts are best when the tank is first loaded. On the 16th of May many light plates were hung in the tank dirtying the contacts with the result of high contact resistances and low ampere efficiency. This low ampere efficiency was caused by the light plates short-circuiting.

ANALYSIS OF TANK RESISTANCES.

| | Volts. |
|---|---|
| Current (amperes)..... | 4000 |
| Current density (amperes per square foot) | 11 |
| Tank voltage ..... | 0.230 |
| Drop between anode and anode bus-bar... | 0.0330 |
| Drop between cathode and cathode bus-bar. | 0.0180 |
| Drop across electrolyte ..... | 0.1790 |
| Per cent actual effective energy ..... | 77.8000 |
| Per cent energy lost in contact and transmission.. | 22.1000 |
| Per cent unaccounted for ..... | 0.1000 |
| Total ..... | 100.0000 |

The drop across electrolyte (0.1790) means from surface of anode to surface of cathode, including the drop across the layer of slimes on the surface of anode, which is about 0.007 volts.

The percentage energy lost in contacts and transmission includes the contact losses, the transmission over bus-bars and supporting bars and the losses in passing current through the body of anode and cathode, but does not include the loss in leads from dynamo to tank.

The results of the tests on tank leakages conducted by Mr. F. I. Cairns, Met. Eng., and myself, are all marked on the drawing, and show the leakages from tank to tank, aisle to aisle, and tank to ground.

## INSULATING PAINTS.

By Maximilian Toch.

Twenty-five years ago insulating paints were virtually unknown, and with the introduction of electrical apparatus materials had to be employed for the purposes of protection, and a new field in the varnish and paint industry was opened. It is not the purport of this article to discuss the merits or demerits of insulating paints that are on the market, because the majority serve their purpose temporarily at any rate. Some are decidedly harmful, some are beneficial. All insulate to a greater or lesser degree.

The materials employed in the manufacture of insulating paints and varnishes consist principally of resins in a suitable solution. It is reasonable to suppose that no manufacturer who understands anything of the nature of the material would add a metallic element to the insulating paint, which would increase its conductivity, yet there are insulating paints on the market that are of such composition, and these are harmful to a great degree.

The principal gums that are used in making insulating varnishes are rosin, asphaltum, pitch, tar, kauri, manilla, shellac and copal. The principal solvents are turpentine, benzine, benzol, acetone, alcohol, bisulphide of carbon linseed oil, china wood oil, and in some instances water. Rosin is very largely

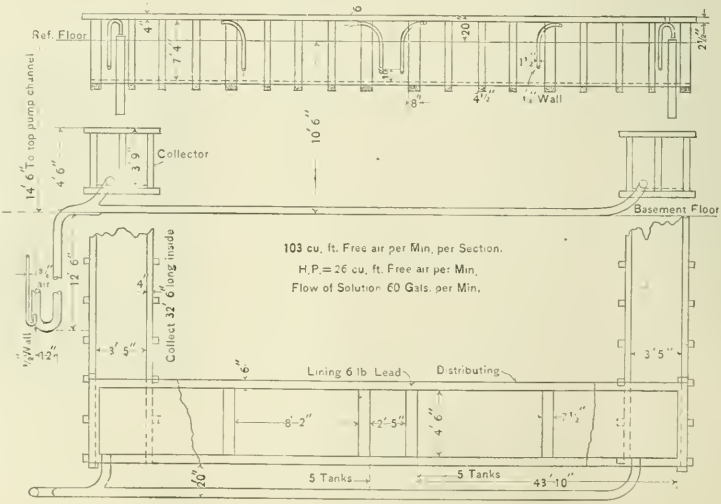



FIG. 5.—VIEW OF ONE ROW OF TANKS, SHOWING METHOD OF CIRCULATION.

used as a gum and on very fine work a solution of rosin alone is rather dangerous, because, being a very strong organic acid; it will corrode a copper wire in a very short time? The same may be said of tar. There is no one insulating paint which can be used for all purposes, but the nearest approach to this would be a paint which contains no rosin, is acid and alkali proof and will stand a fair degree of heat. Some factories buy a paint which they use for painting vats, smoke stacks, insulating wires generally, and which is cheap enough for all purposes, and good enough for any purpose.

Many electrical concerns, however, depend upon the manufacturer of these paints to supply them with an article which is made by a chemist who has sufficient knowledge of electricity to know to what uses the material is put.

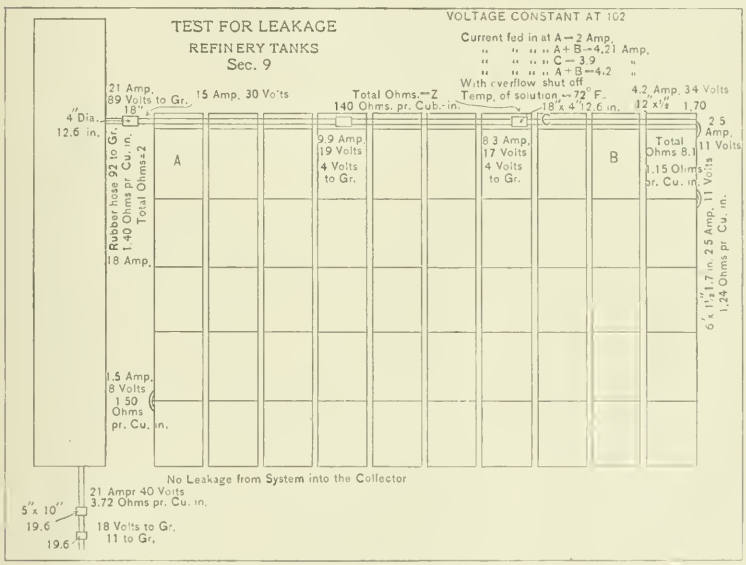

TEST FOR LEAKAGE
REFINERY TANKS
Sec. 9
VOLTAGE CONSTANT AT 102
Current fed in at A—2 Amp.
" " " " A+B—4.21 Amp.
" " " " C—3.9 "
" " " " A+B—4.2 "
With overflow shut off
Temp. of solution—72° F.
21 Amp. 89 Volts to Gr.
15 Amp. 30 Volts
Total Ohms—Z 140 Ohms. pr. Cub.-in.
18"x 4" 12.6 in.
4.2 Amp. 34 Volts
12 x 1/8" 1.70
4" Dia. 12.6 in.
2.5 Amp. 11 Volts
Rubber hose 92 to Gr. 1.40 Ohms pr. Cu. in. Total Ohms=2
A
9.9 Amp. 19 Volts 4 Volts to Gr.
8.3 Amp. 17 Volts 4 Volts to Gr.
B
Total Ohms 8.1 1.15 Ohms pr. Cu. in.
18 Amp.
6"x 1 1/2"x 1.7 in. 2.5 Amp. 11 Volts 1.24 Ohms pr. Cu. in.
1.5 Amp. 8 Volts 1.50 Ohms pr. Cu. in.
No Leakage from System into the Collector
21 Ampr 40 Volts 3.72 Ohms pr. Cu. in.
5"x 10" 19.6
18 Volts to Gr. 11 to Gr.
19.6

FIG. 6.—TEST FOR LEAKAGE—REFINERY TANKS.

## INTERNATIONAL CONGRESS FOR APPLIED CHEMISTRY.

Report of the Proceedings of Section X.
(Electrochemistry and Physical Chemistry.)
By H. DANNEEL, PH. D. AND J. K. CLEMENT.
(Concluded from page 543.)

After the session on June 5, afternoon, Prof. Marckwald, of Berlin, delivered an interesting address on radio-active substances. He performed a series of lecture experiments with radium preparations, and also with radio-tellurium, which he himself discovered. Radio-active bismuth, which is obtained from pitchblende, is precipitated as a chloride with $SnCl_2$. The precipitate thus obtained contains 90 per cent ordinary tellurium. This is converted into its chloride and treated with hydrazin hydrate, which separates out the inactive tellurium, while the radio-tellurium remains in solution. The latter is again precipitated with $SnCl_2$. In this way from 4000 kilograms of pitchblende a few milligrams of the pure radio tellurium may be obtained. This radio-tellurium occasions unusually strong fluorescence. The speaker performed a number of the usual lecture experiments with his preparation.

The following papers by Bodlaender and Grossman were presented in the morning session of June 6; the other papers read in this session having been reported in our October issue, pages 509 to 512.

### THE TECHNICAL IMPORTANCE OF CATALYSIS.

G. BODLAENDER presented an interesting address which enumerates the various cases in which catalysis has found technical application. Since it does not permit of further abstraction, nor deals with any electrochemical questions, a complete report may be dispensed with.

### THE ABILITY OF RHODANIC IONS TO FORM COMPLEX COMPOUNDS IN COMPARISON WITH THAT OF HALOGEN IONS AND CYANIC IONS.

A paper on this subject was read by H. GROSSMANN. According to Abegg and Bodlaender's theory of electro-affinity, the tendency of an ion to combine with other ions or neutral bodies to form complex ions is a measure of its "strength," i. e., the force with which it holds fast its ionic charge. The weak cyanic ion forms complex ions most readily. After that comes iodine. Chlorine goes into complex ions with difficulty and fluorine not at all. The speaker showed that with respect to its ionic "strength" the rhodanic ion lies between iodine and bromine. It forms complex ions less readily than iodine, and more readily than bromine, and we have the following order; F, Cl, Br, SCN, I, and CN. Then follows a list of reasons in support of this view, especially the solubility of HgSCN in the various alkaline haloides.

The discussion dealt principally with the details of the investigation. Abegg called attention to the fact that the tendency to form complex compounds cannot always be determined from the amount of hydrolysis. The hydrolysis depends on the dissociation constant of the acid and this does not always run parallel with the formation of complexes. For example, acetates have much less tendency to form complexes than oxalates, although the latter have larger dissociation constants.

### SESSION ON THE AFTERNOON OF JUNE 6.

### THE PRACTICAL APPLICATION OF ENDOSMOSIS AND THE COLLOIDAL STATE.

A paper on this subject was presented by BREDIG. It is well known that when the cathodic and anodic parts of an electrolytic cell are separated by a diaphragm, the liquid is very often forced through the diaphragm by the action of the electric current. We must distinguish between those cases in which the liquid passes through unchanged, and those in which a change of concentration takes place. The first case is called endosmosis or cataphoresis. The speaker gave the historical development of our knowledge of electrical endosmosis. G. Wiedemann found that the amount of fluid driven through a diaphragm by electrical endosmosis in the unit of time is proportional to the current density and independent of the thickness and cross-section of the diaphragm. The speaker called attention to the analogy of electric endosmotic phenomena with resorption in living organisms, brought out by the investigations of Colnheim and others. G. Quincke showed that by means of the electric current fluid can be driven through capillary tubes and that a diaphragm can be considered as a number of capillaries lying side by side. He

also showed that both the amount and the direction of electrical endosmosis depend on the nature of the liquid, and on that of the diaphragm. The movement of suspended particles by the electric current is a special case of electrical endosmosis. There is no essential difference between this and the more general case. In the latter case the diaphragm is stationary, and the fluid moves; in the former the fluid remains at rest and the suspended particles migrate toward an electrode. Quincke found that platinum, gold, copper, iron, graphite, quartz, feldspar, manganite, asbestos, emery, burnt clay, kaolin, bubbles of oxygen, hydrogen and air, sulphur, silk, cotton, starch, lycopodium, carmine, paper, quills, ivory, oil of terpentine, carbon disulphide, carbon dioxide, and ethylene, when suspended in water, move in the direction opposite to the current, i. e., towards the anode. Suspended in terpentine oil, most substances with the exception of sulphur, move in the direction of the current. Thus, the nature of the fluid and of the suspended particles determines the direction of the latter's movement. Quincke's theory for the phenomenon is that there is a difference of potential between the liquid and the diaphragm or suspended substance, and that, if the suspended particles have a positive charge, e. g., with respect to water, they must move towards the negative pole. According to Quincke the velocity of the motion is proportional to the current density.

Helmholtz then formulated a complete mathematical theory of electrical endosmosis, and of the reverse of the phenomenon—the so-called "diaphragm current," discovered by Quincke. If by means of an electric current we can bring about a motion of the charged particles with respect to the fluid, vice versa by pressing a liquid through a diaphragm, we can generate an electric current.

Coehn formulated an empirical rule for the sign of the charge. According to Coehn's rule the medium with the higher dielectric constant is always charged positively with respect to the other. With respect to water, which, with the exception of HCN and $H_2O_2$ has the highest dielectric constant, the suspended particles are, as far as we know, mostly negatively charged and move towards the anode. Nernst says in regard to this point that each of the layers enveloping the two heterogeneous substances at the point of contact contains ions, and that the coefficient of distribution between the two mediums is different for every ion, so that a separation of the ions results. The explanation of Coehn's rule is that the solubility of the ions in the different mediums is closely connected with the dielectric constants of the latter. According to Knoblauch the latter depends also on the velocity of the diffusion of the ions from the one medium into the other.

Nernst has emphasized that a very important and fundamental question which has not yet been satisfactorily answered is here involved—the question of the origin and of the absolute value of the differences of potential between mediums in contact with each other. Small quantities of impurity, if they cover the surface of contact, can, even in very thin layers, cause a complete reversal of the phenomenon. In close relation with the phenomena of electrical endosmosis, and perhaps of equal importance, is the migration of colloids with the electric current. Colloidal solutions of arsenic sulphide, antimony sulphide, copper sulphide, cadmium sulphide, silver, gold, platinum, aniline blue, indigo, fuchsine, tannin, caramel, starch, haemoglobin, mastic and gamboge go towards the anode; ferric hydroxide, methyl violet, Hoffman's violet, and magdala on the other hand go to the cathode. Since the heterogenity of such colloidal solutions is made probable, or, perhaps, certain by a number of their properties, colloidal solutions can be considered as a suspension of ultra-microscopic particles and then every difference between the migration of colloids and actual electrical endosmosis disappears.

It is interesting that the direction of migration of certain colloids, e. g., albumen, is changed by slight variations in the composition of the fluid. The direction in an acid solution is, for example, opposite to that in alkaline solution. There must, therefore, be a certain concentration of hydrogen ions at which albumen no longer migrates by electric endosmosis and the albumen molecules have no potential difference with respect to the medium. According to Hardy, the discoverer of this phenomenon, albumen can be most easily coagulated at this point. This result of Hardy's requires further confirmation. It is well known that colloids are very easily coagulated with electrolytes. Quincke says that there is no connection between coagulating action and electrical conductivity, but to any one who has made similar experiments, the distinct difference between the precipitating action of electrolytes and non-electrolytes is unmistakable.

Hardy found that suspensions and colloids which move toward the anode are precipitated especially easily by cations, while those which move toward the cathode are precipitated more readily by anions. According to Schulze the precipitation takes place the more readily the greater the valency of the ion in question, and according to Spring the migration velocity of the ion is a joint factor.

In conclusion the speaker referred to an attempt of his own to connect the facts of the electrical opposition between suspension and fluid with the phenomena of coagulation, sedimentation, absorption and capillarity. Whitney and Billitzer found that in the coagulation of certain colloids by means of various salt solutions products of the electrolytic dissociation of the salts are formed in equivalent amounts. This would indicate electrolysis in accordance with Faraday's law. The circumstances connected with the coagulation of suspensions closely resemble the phenomena which Palmaer observed with drop electrodes. The speaker believes that coagulation is most intimately connected with capillary electric phenomena. The relation between chemical composition and surface tension at the boundary of two mediums is of fundamental importance.

Removing Water from Peat-Bog by Electric Endosmosis.

Following Prof. Bredig's address, Count Schwerin demonstrated a number of experiments bearing on the technical application of endosmosis.

If by the application of an external electrical potential difference a fluid can be made to pass through a porous earthenware cell or any other material which has a different dielectric constant from that of the fluid, then, on the other hand, particles suspended in the liquid must move through it. This phenomenon can be utilized in a number of cases in which it is difficult to remove the suspended particles from the liquid. There are, for instance, precipitates which cannot be filtered, and which require a long time to settle. By passing an electric current through such a suspension the suspended particles can be deposited in a firm layer on one of the electrodes. The speaker performed several experiments. A liquid suspension consisting of 20 per cent alizarin and of clay and peat was contained in a lead dish. An electrode of sheet zinc dipped in the liquid. By making the dish the cathode and the zinc electrode the anode, the suspended substance was deposited so firmly on the zinc plate that it could only with difficulty be cut away with a knife. It is possible in this way to almost free the water of the suspension. This process might be applied technically in removing water from peat-bog.

On account of the dirt, stone, earth, etc., which it contains, peat cannot be used as fuel for many purposes without being worked over. It must therefore be ground and washed. The product of the washing is a slimy mass which is very difficult to free from the 85 to 90 per cent of water which it contains. Filtration is impossible; peat does not settle; and evaporation of the water would cost more than the peat is worth. The peat sludge can be freed from the greater part of its water by electric endosmosis. When the sludge is placed in a wire net which is fine enough to keep the particles of turf from passing through, the water does not run off on account of adhesion. When a sheet of metal is laid on the sludge above

the wire net and connected to the positive pole of an electric circuit, and the net connected to the negative pole, the peat moves toward the metal plate and the water in the vicinity of the wire net is freed from the peat so that it can run off freely. The speaker performed the experiment. So long as no current flowed the wire net appeared to be watertight, but immediately on closing the circuit the water ran off rapidly. A similar but smaller apparatus, containing alizarin paste, acted in the same way.

In the discussion which followed, PROF. LUNGE, of Zürich, remarked that the dephlegmation of peat is a very old problem, and on account of the large deposits of peat on the earth, a very important one. This is a new illustration of how great scientific results can arise from apparently abstract theoretical researches. Replying to an inquiry the author remarked that after having treated peat by this method, 65 to 70 per cent water still remains. Suchy inquired whether the amount of water removed corresponds to a sort of Faraday's Law. Schwerin, Bredig, Coehn and LeBlanc cited examples showing that with one and the same material the amount of water removed is proportional to the quantity of electricity which is passed through, but that the amount of water corresponding to a given number of coulombs varies with the nature of the suspended substance, and with the size and shape of the grains.

In reply to an inquiry of Nernst's, Mueller von Berneck stated that electrolysis with the evolution of hydrogen and oxygen takes place, but that the two volts required for the electrolysis are of no consequence compared to the pressure required for dephlegmation, since 4 or 5 volts are required per centimeter of peat deposit. Freyss remarked that ore slimes can be freed of water by this means. Lunge called special attention to the working of gold fields where the slimes are often the source of great inconvenience.

### CATALYSIS.

Then followed a lively discussion of the papers of Schenck, Bodenstein and Bodlaender on gas reactions in the presence of a catalytic agent. Schenck had discussed the decomposition of carbon monoxide in the presence of iron, Bodenstein and Bodlaender the formation of $SO_3$ from $SO_2 + O$ in the presence of finely divided platinum. The point at issue was whether it is permissible to deduce the order of such reactions from the reaction velocity. The discussion furnished a number of instigations for further investigation, but for the present it is outside of the field of electrochemistry, and as no decision was reached, a mere reference will suffice. The discussion is printed in detail in the *Zeit. f. Electrochemie*, Vol. IX., p. 742-751.

### WINES CONTAINING GYPSUM.

MAGNANI read a paper on the inversion velocity of sugar in solutions of wine and gypsum. It has been asserted that in wine which contains gypsum, acid salts are formed which are injurious to health. The presence of acid salts would greatly accelerate the inversion of sugar. The speaker found that in a great number of wines no acceleration takes place and claims therefore that wines containing gypsum are not injurious to health.

### CATALYSIS.

SABATIER read a paper on the addition of hydrogen (to organic compounds) by catalysis. Sabatier and Sendernes have found that when acetylene is passed over metallic nickel it is readily polymerized. When hydrogen and acetylene are passed over nickel together the acetylene combines with the hydrogen to form saturated hydrocarbons. These researches were published last year in *Comptes Rendus*.

The following experiments are of technical importance. The speaker was successful in obtaining the reduction of nitroderivatives, the synthesis of naphthene, and the conversion of aldehydes and ketones into alcohols. The metal acts catalytically, but its catalytic action is destroyed by the presence of traces of impurities, e. g., when the hydrogen contains arsenic or sulphur.

### THE ROLE OF THE CATHODE MATERIAL IN THE REDUCTION OF NITROBENZOL.

LOEB presented a paper on this subject and described experiments made in conjunction with R. Moore. The principal product of the electrolytic reduction of nitrobenzol suspended in aqueous solutions of caustic soda on platinum, nickel and mercury cathodes is azoxybenzol; on lead, tin or zinc electrodes, also on copper cathodes, especially when copper powder is present, anilin is formed. The object of their experiments was to ascertain what role the cathode material plays in these reactions, to determine whether the reduction energy depends simply on the potential of the cathode, and which ions perform the work of reduction.

The author first measured the potentials of the various metals in dilute sodium hydroxide by different current densities and then the same in the presence of nitrobenzol. The difference of the two values by a given current density they designated as the "depolarization value" of nitrobenzol for this density. The "depolarization values" for platinum and most of the metals which are attacked by chemical action were found to decrease with increasing current density. An explanation of this phenomenon is that, with increasing strength of current, the reduction velocity of nitrobenzol increases because of a greater number of reducing ions arriving at the cathode. As these ions are held back in the electrolyte by the process of reduction their osmotic pressure increases while the electrolytic "solution pressure" does not essentially change. Thus with rising current density the depolarization values decrease. The depolarization curve for copper, on the other hand, shows periodic fluctuations. With increasing current the curve alternately rises and falls. The probable explanation for this is that nitrobenzol is very slowly reduced by copper, and the resulting phenylhydroxylamine very rapidly.

At the beginning of the experiment copper is deposited on the cathode, and since the osmotic pressure of the copper ions is thus diminished the "depolarization value" rises. As soon as the hydroxylamine phase has reached a certain value the dissolution of the copper sets in with great rapidity; the osmotic pressure of the copper ions rises and the "depolarization value" falls. When the phenylhydroxylamine has been used up the opposite effect sets in. This process goes on repeating itself periodically.

It follows from the experiments that the specific action of metals can be regarded as electric potential action, and that by artificially maintaining a constant electrode potential the same reduction process could be obtained on any electrode. This standard potential is not as has always been assumed the absolute cathode potential, but the "depolarization value" and it varies with the current density. It has been experimentally proven that in the same electrolyte, and by the same temperature on different attackable and non-attackable electrodes kept at constant potential the same products can be obtained and in almost equal yields.

## SESSION ON JUNE 8.

### ELECTROPLATING PLANTS.

Under the title "Installing of Electroplating Plants" SACKUR talked about improvements in the arrangements of works, e. g., about new processes for nickel plating, zinc, for removing tin plate. He spoke about dynamos, electrical measurements, composition of baths; about grinding machines, boiler plants, etc. and finally described in detail a plant which he had erected himself.

### QUANTITATIVE DEPOSITION AND SEPARATION OF METALS BY ELECTROLYSIS.

A paper on this subject was presented by NISSENSON AND DANNEEL. A number of methods were described which have stood the test of practice, and the determination of Pb, Cu, Sb, Sn, Co, Ni, Zn, and Cd was discussed by Nissenson. Dan

neel discussed the questions under what conditions are metals at all deposited and under what conditions are they deposited in a compact, weighable form. The first question is completely answered by Nernst's formula. To apply the latter, besides knowing the "solution potentials" of all the metals (their "single potentials" in a solution which is normal with respect to the metal in question), one must know the ionic concentrations in the solutions out of which the metals are to be deposited. We know the "solution potentials" of most of the metals, but we know almost nothing about the ionic concentrations in most of the solutions which are used in practice. To supply this knowledge is the most important problem of electro-analysis. Until this has been done electro-analysis will continue to be an empirical art.

Concerning the question as to the conditions under which metals are deposited in compact, weighable form, we have as yet only empirical conceptions. Metals are said to be best deposited when the separation is the result of a secondary reaction. The speaker is of the opinion that secondary separation takes place only in a very few cases. The evolution of hydrogen by the electrolysis of potassium chloride solutions is generally said to be a secondary reaction; a simple calculation with Nernst's formula shows that in order to separate out potassium before hydrogen there would have to be $10^{48}$ kg. of potassium ions per liter.

The author develops the following picture of the deposition of metals. Consider a rough electrode, with projections and cavities in a solution of $AgK(CN)_2$. Since electric current always follows the lines of least resistance, and the metals offer less resistance than the electrolyte, the current lines will converge toward the raised places. Consequently these points will be impoverished of silver ions, the voltage required to separate out the metallic ions then increases in accordance with Nernst's formula and these paths are no longer the lines of least resistance so that the current lines bend toward the deeper parts of the electrode until impoverishment of silver ions occurs again, and so on. The result is that with medium current density the current lines will be uniformly distributed over the surface of the electrode, and that the coating will be, therefore, uniform. The exceptions to the above, and the difference between complex and simple salts are apparent from the following consideration.

Impoverishment of metal ions is *produced* (a) in all solutions by the liberation of metal ions; (b) in all complex salts by the increase of the ions of the salt which forms the complex compound with the metallic salt, e. g., of CN ions, in $AgK(CN)_2$ solutions, by which according to the law of chemical mass action the concentration of silver ions is diminished:

$$K^{\cdot} + Ag(CN)'_2 = K^{\cdot} + Ag^{\cdot} + 2CN'$$

(c) in all complex salts which form complex anions containing the metal to be deposited, the latter are carried away by the current from the cathode.

Impoverishment of metallic ions at the cathode is *counteracted* by:

1. Diffusion is greatest where impoverishment is greatest, and where the cross-section of the diffusion lines is greatest; i. e., on edges and corners.

2. Ions resulting from fresh dissociation. As long as the dissociation velocity is very small compared with the velocity of the other processes which furnish or carry away ions—this can be assumed to be the case with all good depolarizers—the furnishing of fresh ions by dissociation does not influence our considerations.

3. In simple salts and in those complex salts which form a cation containing the metal in question, the current brings new metal ions to the cathode, and the effect is greatest where the number of current lines is a maximum.

4. Local currents. If the impoverishment on the electrode is not uniform, short-circuited concentration cells will be formed on the electrode, and these will neutralize the impoverishment. This really means that the distribution of the current lines over the surface of the electrode tends to be uniform.

The difference between complex and simple salts is: With complex salts which contain the metal in the anion *a, b, c,* 1 and 2 act and a uniform deposit will be here most readily obtained. In complex salts which contain the metal in the cation *a, b,* 1 and 2 act. In simple salts *a,* 1, 2 and 3 act, and an uneven deposit is therefore most likely to occur in simple salts. This explains why a better deposit of silver is obtained from a potassium cyanide solution, than from silver chloride.

If the current density is so small that there is sufficient time for diffusion to prevent considerable impoverishment of the ions near the electrode, there is no longer ground for the current lines not conveying towards the highest points of the electrode, and the metal grows into large, well developed crystals, as, for example, in a silver voltameter at small current densities. On the other hand, with current densities at which the processes counteracting the impoverishment of metal ions are unable to fully prevent it, the metal will be uniformly deposited. If this were not the case we should never be able to obtain a smooth metallic coating. With increasing current density the ionic concentration at the electrode becomes less. When the latter falls below a value which makes the potential at which the metal is separated out equal to the decomposition voltage of hydrogen we obtain a loose, spongy, crystalline metal due to hydrogen being simultaneously evolved. A spongy deposit is especially easy to obtain with metals which form alloys or compounds with hydrogen, e. g., silver, gold and platinum.

In the discussion Foerster expressed the same opinion about our slight knowledge of analytical electrochemistry. The methods which are already known should undergo a thorough, systematic rearrangement. Bodlaender thought that the question as to whether a metal is primarily or secondarily precipitated could not be decided from Nernst's formula. There might be other phenomena such as the formation of alloys, for example in the "over-voltage" of hydrogen, which cause a precious metal to be precipitated before a base metal.

### Low Temperature Researches.

G. Monti presented a paper on industrial applications of the concentration of solutions by freezing and the production of low temperatures by the action of concentrated solutions on ice. He tried to concentrate the poor wines of 1901 by freezing them. He found that the concentrated solutions, instead of accumulating in the center of the block of ice, collected between the small ice crystals. He described his method for continuously extracting the wine from the ice crystals. He also described a number of simple methods for producing the low temperatures which he required.

### Polishing Carbon Plates and the Lighting of Ions.

Von Bolton presented a paper on the emission of light by the ions. If a carbon electrode which is connected with the positive pole of a battery (giving about 110 volts) be dipped in sulphuric acid, another electrode completing the circuit to the negative pole, a layer of oxygen is formed about the carbon electrode. The oxygen is pierced by numerous small electric arcs and emits a bright yellow light. If, after some time the electrode is removed, it will be found to be brightly polished. The firm of Siemens & Halske has patented this process for polishing carbons. Metals behave similarly to carbon when connected to the positive pole, and their surfaces are polished. When metals are used as the negative electrode they emit a different light, the color of which varies with the nature of the metal. Copper, for example, emits a green-blue light, lead violet, aluminium green, magnesium blue-green, etc. The metals of the platinum group Pt, Ir, Pd, Rh, and Ru all light in different colors: Pt violet, Ir and Pd green. The speaker thinks that the ions produce the light as, at the moment of liberation, they pass through the layer of oxygen. Most beautiful spectra can be obtained from this light. Spectra of the alkaline earth metals obtained in this way are better and

stronger than those obtained from a spark between a solution and a platinum point.

The ionic spectrum of strontium shows seven brilliant lines in the green which are scarcely to be noticed in the spectrum from the ordinary spark.

Spectra of metals which are not attacked when exposed to the air can be obtained by dipping them in $HNO_3$, which is diluted with four parts of water. The acid solution is contained in a spherical glass vessel. An open glass tube, in which the negative electrode is suspended, is introduced through an opening in the top of the sphere. It reaches almost to the bottom of the tube and separates the negative electrode space from the positive, thus avoiding the formation and explosion of oxyhydrogen gas. The metal to be investigated is attached to the negative electrode.

The aluminium spectrum which was exhibited by the author is characterized by remarkable, broad bands in green and blue and extending into violet. It appears as though one were looking into hollow half cylinders which were dissected perpendicular to their axes and apparently illuminated from left to right. A number of other metals have similar "cylinder bands." These "cylinder bands" differ considerably from ordinary spectrum bands. For example, the magnesium "ionic spectrum" has two green "cylinder bands" whose illumination is opposite to that of aluminium, i. e., from right to left, from the violet end of the spectrum to the red.

The author uses a similar but smaller apparatus to investigate the "ionic spectra" of dissolved salts. A platinum wire serves as negative electrode. With this apparatus extraordinarily small quantities of salts can be qualitatively determined, e. g., 1 milligram $Na\,NO_3$ in 10 Liter $H_2O$ gives a good test for sodium. One milligram thallium nitrate in 1 liter $H_2O$ gives the green thallium lines very clearly. After three washings with distilled water and filling with $NaNO_3$ the green thallium lines could still be distinctly seen. The test for strontium is just as delicate.

In the discussion which followed, Elbs inquired if it were possible that carbon compounds were formed on the polished carbon electrode, and that these cover the electrode with a glossy varnish, the carbon being sticky after the experiment. Von Bolton said he has made no experiments in this direction. The fact that the electrolyte becomes turbid and black would indicate that the carbon pulverizes and dissipates in powder form through the electrolyte. It may be that graphite is formed on the surface of the electrode. Coehn asked whether a precipitate is deposited on the cathode after the electrolyte has become black. Such a precipitate could be attributed to the carbon being dissolved at the anode and separated out at the cathode. Von Bolton replied that he had obtained a black deposit on platinum cathodes, but did not know whether it was carbon. An excellent carbon precipitate is formed on aluminium cathodes, even when the solution has been filtered and the suspended particles removed. Coehn concludes from this that the carbon is electrolytically dissolved and precipitated in accordance with Faraday's law.

Arnot thought that the color phenomena which Bolton had observed were not due to the emission of light from the ions, but to the pulverization of the metals. The small metallic particles were vaporized by the high temperature and the colored light was emitted from the metal vapors. Von Bolton replied that if this were true the same light effect should be obtained with metallic anodes, but this is not the case, although the temperature at the anode is higher than at the cathode. If the light were due to metallic vapors, the oxide spectrum ought to be visible. Furthermore Bolton thought it impossible for the ions to be first discharged and then to emit light as molecules.

Martens thought that Bolton's apparatus was like the Wehnelt interrupter. The latter works quite differently when the poles are reversed and therefore it is to be expected that when the poles in Bolton's apparatus are reversed the light effect will be different. He asked whether the method could be applied to spectrum analysis. Bolton replied that with some metals one obtains all the lines which appear in the ordinary spectrum, with some metals less than in the ordinary spectrum and with others more. All disturbing extra lines, such as, for example, those caused by the air in the spectrum from an electric spark, are absent from the "ionic spectrum." The metallic spectra obtained in this way are always pure. With most metals, Zn and Cd excepted, the $H\alpha$ line is obtained.

In reply to Martens, who said that he did not believe the method was of any practical value, Von Bolton replied that he made mixtures of different salts and obtained all the lines of the components, he found that the addition of sodium often raised the brightness and brilliancy of the spectrum. If one takes brass or a nickel coin and treats it according to this method, one will immediately see the copper and nickel spectra. The nickel lines will be weaker than those of copper. With zinc and copper all the lines of both spectra can be seen wonderfully clear. As zero point he has always taken the $H\alpha$ line of the hydrogen spectrum taken from a Plucker tube.

ELEMENTARY THEORY OF ELECTROLYSIS OF SODIUM CHLORIDE WITH DIAPHRAGMS.

A. GUYE presented a paper on this subject. F. Foerster and his scholars have shown that the output of sodium hydroxide by the electrolysis of alkaline chlorides with diaphragms at any instant is given by the equation $r = 1 - nx$ in which $n$ is the "transport number" of the alkali and $x$ is that fraction of the unit of current which is transported by the alkali. $x$ is a function of the electrical conductivity of the alkaline chloride and of the hydroxide, or, what amounts to the same thing, of the concentrations $c$ and $C$ of alkaline chloride and hydroxide, and of the temperature. A more careful study of the changes of $r$ shows that, under the conditions of experiment which generally underlie technical electrolysis, $r$ may be considered as a function of a single independent variable, namely, the concentration of the alkali $c$ (expressed in gram-molecules per liter).

We have then the equation,

$$r = f(c)$$

Under the assumptions it is easy to derive the fundamental formula for the course of electrolysis. When the quantity of electricity $dF$ flows through the electrolyte $rdF$ grammolecules NaOH are formed in the cathode space. If we denote the volume of the liquid at the cathode with V the increase of the concentration is V $dc$ grammolecules of NaOH. These two quantities are equal:

$$rdf = V\,dc \text{ or } dF = V\frac{dc}{f(c)}$$

or when we integrate from F = 0 to F = m and from c = o to c = c:

$$m = V\varphi(c)$$

in which $\varphi(c)$ is the definite integral of the second term of the foregoing equation. Experiments in the Physical Laboratory of the University of Geneva have shown that for $r = f(c)$ we can substitute the expressions

$$r = \frac{1}{(a + c)} \text{ or } r = \frac{1}{a + c}$$

with sufficient exactness, the former when the cathode solution is saturated with sodium chloride, the latter when it is not saturated. Numerical verifications of these formulas both from laboratory experiments and experiments on an industrial scale show that the above elementary theory of diaphragm cells agrees very well with practice.

In reply to a question from Foerster, Guye explained that the formula $r = \frac{1}{(1 - ac)}$ applies to solutions in which the concentration of sodium chloride is constant. When the con-

centration changes according to Faraday's law, the formula $i = \frac{I}{1 - ac}$ is the one to be applied. The experimental results of Foerster and his students are all somewhat smaller than those calculated from the formula. Van't Hoff asked if a better yield could not be obtained by removing the hydrogen which adheres to the cathode, for example, by rotating the cathode, and thus reducing the resistance of the cell. Guye had obtained the same results with rotating cathodes as with stationary ones.

### Manufacture of Bisulphide of Carbon in the Electric Furnace.

In the session of June 4, Mr. E. R. Taylor, of Penn Yan, N. Y., presented a paper on this subject. This was the only paper read by an American before the electrochemical section of the Congress. The author first discussed the disadvantages of the use of externally heated retorts for manufacturing bisulphide of carbon, and then described the type of electric furnace developed by him for this purpose. Since this furnace has been repeatedly described in Electrochemical Industry (October 1902, pp. 60, 63, 76), reference to our former description must here suffice.

The author said that his furnace gives the possibility of uniformly obtaining the most suitable temperature (very high, very low, or anywhere between) for any given furnace reaction, and maintaining the same without fluctuation for days, weeks or even months together. All materials, after having once been placed in the furnace, feed uniformly by gravity and fusion, giving such unity to the whole as to give the best possible results from an economic point of view. He has made in his furnace 15,000 pounds in twenty-four hours, and with more electric power in the same furnace, 25,000 pounds can readily be made in that time. The larger the furnace, the easier it can be worked.

## ELECTROCHEMISTRY AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

A new laboratory devoted exclusively to electrochemistry was opened at the beginning of the school year at the Massachusetts Institute of Technology to provide facilities for the professional work in the senior year of students electing the schedule of electrochemical studies and for graduate students desirous of taking up this line of work.

Instruction in electrochemistry has been given to students in physics since 1894, but the recent rapid development of the industrial applications of the science determined the department several years ago to extend the work and to lay out a schedule of studies directed particularly to this end. This course was officially announced by the Institute in the summer of 1900.

In the new laboratory each student's desk is provided with 2, 12½, 25 and 110-circuit, rheostat, stirrer, gas, water and suction. Besides an equipment for analytical work, each student is given a complete set of electrochemical measuring apparatus, including a Weston ammeter and voltmeter with three scales, Lippmann electrometer, potential boxes, conductivity bridges, voltameters, etc. The whole class is thus able to work at the same time on subjects which are being concurrently discussed in the lectures, and thus, in conferences held weekly on the current work, to compare results of each other's experiences. The laboratory is also equipped with special arrangements for electrochemical analysis. Special rooms adjacent to the laboratory are equipped for measurements of electrical conductivity, dielectric constants, etc. Special generators have been installed to give direct or alternating currents for electrolytic and furnace work, and to allow considerable variations of voltage.

## HISTORICAL SKETCH OF THE DEVELOPMENT IN THE PRODUCTION OF COPPER, NICKEL AND ZINC FROM CHLORIDE SOLUTIONS.

By William Koehler.

(Concluded from page 542.)

In the year 1893 Dr. Carl Hoepfner came to America for the purpose of demonstrating his process to the Canadian Copper Co. A small experimental plant was then built at the above-named company's works at Brooklyn, Cleveland, Ohio, under the direction of Messrs. Hoepfner and Wannschaff. The process as here shown was carried on in much the same manner, and with the same apparatus as at the works of Mr. Throm in Giessen, Europe. Copper and nickel of good quality were produced and the feasibility, together with the practicability, of the production of metals from pure chloride solutions were demonstrated.

At this time Dr. Hoepfner did not limit himself to the production of copper and nickel as shown and demonstrated but claimed the possibility of the direct refining of these metals from chloride solutions, using copper-nickel anodes, or in case of copper alone, copper anodes making the process similar to the present refining of copper from sulphate solutions using crude metal anodes. In the case of nickel refining, nickel anodes were to be used in a neutral or slightly acid solution of nickel chloride.

In 1894 the experiments carried on by Dr. Hoepfner and Dr. Wannschaff on one side, and Mr. David H. Browne, representing the Canadian Copper Co., on the other side, terminated. Mr. Browne ceded the fact that good copper and nickel were produced, but that the process did not come up to the requirements of his company, and, therefore, negotiations towards installing a larger works came to a close. In the meantime the zinc process, as described in the *Eng. and Min. Journal*, May 16th, 1903, page 750, by Mr. Emil Guenther, was put into practical operation on a large scale at Furfurt, Germany. During the same year Messrs. Hoepfner and Wannschaff returned to Europe; previously, however, contracts were signed whereby the writer was to go to Europe in the interests of the copper and nickel industry. Preliminary experiments were immediately taken up at the electrolytic bismuth refinery by Mr. George Throm. The abandoned works of Blumrath & Schneider, at Weidenau, Siegen, were again fitted out for the purpose of demonstrations on a larger commercial scale than had been tried elsewhere.

At these works the sheet iron cathodes which had up to date been in use in the nickel electrolysis were replaced by sheet nickel cathodes. The form of the copper baths was changed from a triangular bath to rectangular vats of 3 m. x 1 m. x 1 m (see Fig. 7), thereby conforming more nearly in size and external shape to the baths at present used in refining of copper from sulphate solutions. The circulation of the copper bath was materially changed and the rate of flow or speed of the anode electrolyte greatly increased. The baths were equipped with sixteen cathodes, each of 0.5 square meters active or submerged surface. The chlorine gas evolved in the nickel electrolysis was absorbed in a series of towers and vats by means of crushed matte and a solution of mixed chlorides. The towers were equipped with air ejectors. These ejectors keeping the whole system under a partial vacuum thoroughly prevented the escape or loss of chlorine gas. Another innovation introduced at this time was the application of a jet of superheated steam in the agitation of mattes in a cupric chloride solution, thus dispensing with revolving leaching drums.

The results obtained at Weidenau were of such a satisfactory nature that it was decided to enlarge these works. In order to obtain better facilities than were obtainable at Weidenau, the works were removed to Papenburg, and they are at the present time in a flourishing condition. In 1894 Dr. L. Mond began to take an active interest in the zinc and chlorine industry. Dr. Friedrich Mohr was appointed to thoroughly investigate the

technical side of the question, and after spending some time at Giessen, also at the zinc works at Furfurt, which were under the supervision of Dr. George Eschelmann, it was decided to build a zinc bleach plant in England under the auspices of the Brunner Mond Alkali Co. Through the courtesy of Mr. H. Steinmeister, of the Gesellschaft fur Metallelectrolyse mit Beschraenkter Haftung, I am advised (Aug 19th, 1903) that these works are now operating uninterruptedly with 1200 hp., producing an exceptional quality of zinc and bleach. Further, the copper nickel works at Papenburg are being increased by the addition of another unit of 600 hp. The power consumed at the Brunner-Mond works produce daily about 6000 kilos of zinc and 18,000 kilos of bleach, equalling 6 and 18 tons, respectively.

In the years following 1894, after Messrs. Hoepfner and Wannschaff had returned to Europe, Mr. David H. Browne, of the Canadian Copper Co., again took up the electrolytic production and separation of copper and nickel. Through the efforts of Mr. Browne, who associated with himself Mr. L. R. Vorce and Prof. Langley (Mr. Langley being professor of electrical engineering at Case School of Applied Science), the Browne process was brought into existence. According to patents issued to Mr. Browne, filed in 1899, and granted December 2, 1902, we have the following L. P. 714,861, an invention which has for its object the improved separation of copper and nickel by electrolysis on a commercial scale.

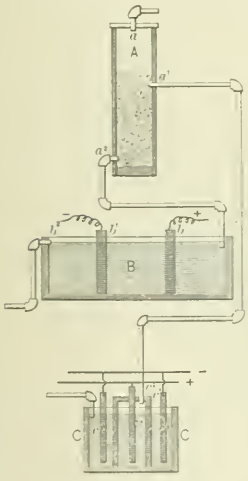


FIG. 3.—BROWNE PROCESS.

In the annexed Fig. 3 is shown one form of apparatus adapted to be used in the Browne process.* Copper-nickel matte is treated by any suitable process to form copper nickel alloy substantially free from sulphur. From the copper-nickel alloy so formed are made in proportions dependent upon the relative amounts of copper and nickel therein contained copper and nickel anodes and copper-nickel fragments or powder

The copper-nickel fragments or powder are placed in the receptacle A, which designates the shot tower, and which is provided with apertures a, a' and a². Such subject matter is there subjected simultaneously to the action of a stream of a solvent for cuprous chloride, such as salt water introduced in the top of the tower at a, and a stream of free chlorine introduced at the side of the tower through the aperture a'. The combined action of salt water and of the heat produced by the combination of the chlorine with the copper nickel alloy, forms a solution of cuprous and nickel chlorides, the reaction being $2CuNi + 6Cl = Cu_2Cl_2 + 2NiCl_2$. Such solution is permitted to run out through aperture a³ and thence into the electrolytic cell B containing an anode b of copper-nickel metal and a cathode b'. The electric current being passed through the solution of cuprous and nickel chlorides, the cuprous chloride is decomposed, the copper plating out upon the cathode, and the chlorine combining with the copper and the nickel of the anode forming cuprous chloride and additional nickel chloride the reaction being.

$$2CuNi + 6Cl = Cu_2Cl_2 + 2NiCl_2$$

The cuprous chloride so formed is also decomposed in the same manner as was that of the original solution, cuprous and nickel chlorides being formed from the anodes as before and copper plating out. In this manner all the copper is plated out, and only nickel chloride remains which nickel chloride is permitted to emerge from the cell at b². The nickel chloride is now freed from any impurities such as iron or traces of copper, the iron being precipitated by an alkali

$$NiCl_2 + Fe_2Cl_6 + 6NaOH = NiCl_2 + 6NaCl + Fe_2(OH)_6$$

The liquor is then heated to a temperature of between 30° and 60° C., and is also increased in strength preferably to a density of from 30° to 50° Baume. It is thereupon introduced into a nickel plating apparatus which may consist of a series of cells such as C, each of which may have a porous diaphragm c and an anode cap $c^1$, a carbon anode $c^2$, a nickel cathode $c^3$, a chlorine escape $c^4$, connecting with aperture $a^3$ of the shot tower A. On the passage of the electric current through this latter solution, nickel is plated upon the cathode, and chlorine gas is liberated at the anode, the reaction being

$$NiCl_2 + \text{current} = Ni + 2Cl$$

Said chlorine gas is then conducted to the shot tower A and is utilized, as previously described, to form the solution of copper and nickel chlorides, the reaction being

$$2CuNi + 6Cl = Cu_2Cl_2 + 2NiCl_2$$

Section 13 of patent claims reads as follows: "In the art of copper separation the process which consists in electrolyzing a solution of nickel chloride, plating out nickel therefrom and separating chlorine therefrom, treating copper nickel matte to form copper nickel alloy substantially free from sulphur, subjecting said alloy concurrently to said chlorine and a solvent for cuprous chloride, plating out copper therefrom and leaving nickel chloride solution substantially as set forth."

Before drawing a comparison between the Browne process and that of Hoepfner, attention is called to a statement in the above patent specification (line 55 to 65 L. P. 714,861). The patent distinctly states the cuprous chloride is formed (using copper and nickel anodes) in the same manner as that of the original solution, cuprous and nickel chlorides being formed from the anodes as before and copper plating out. In this manner all copper is plated out and only nickel chloride remains. The writer does not conceive how it is possible to remove copper completely from a solution when at the same time copper is being constantly introduced into the same solution through the electrolytic disintegration of a copper nickel anode. If a copper-nickel anode be used, copper will always find its way into the electrolyte. The methods of prevention are either to electrolyze the copper-nickel chloride solutions with a nickel anode (containing no copper), thereby enriching the electrolyte in nickel contents, or to electrolyze the copper-nickel chloride solution in the same way as Hoepfner does with an insoluble anode, thereby plating out all the copper leaving the nickel contents of the electrolyte unchanged, and collecting the chlorine gas which will now be given off at the anode according to the reaction

$$Cu_2Cl_2 + \text{current} = 2Cu + Cl_2$$

The copper may also be chemically precipitated from the electrolyte. At the time that Hoepfner demonstrated his process at the Canadian Copper Co.'s works in 1893 and 1894 the old Swedish method of smelting copper nickel ores to copper nickel metal free from sulphur or any other smelting methods for the treatment of high grade matte to form copper nickel alloys were considered too expensive.

The cost of producing copper-nickel alloys from matte therefore excluded a direct electrolytic process using copper-nickel anodes and an electrolyte of cuprous chloride in a solution of salt or calcium chloride. The experience gained from the Marchese electrolytic process using copper matte anodes, namely the brittleness of such anodes, the uneven disintegration of the same, and, lastly, but not least, the separation of sulphur from such anodes when subjected to electrolysis, thereby

* An exact description of the Browne process as it was operated for several years successfully in Cleveland is given in ELECTROCHEMICAL INDUSTRY, July, 1903, p. 381 to 384.—ED

causing an abnormal rise in the potential of the bath, fully excluded the application of anode material carrying from 40 to 60 per cent metal in the Hoepfner process.

The raw material used in the Hoepfner demonstration consisted of from 40 to 60 per cent matte. The best method of comparing the Browne process with the Hoepfner process seems to lie in the comparison of the chemical reactions entering into each. The following reaction, as given to the writer by Dr. George Wannschaff in 1893 and 1894, while this gentleman was demonstrating the Hoepfner process at the works of the Canadian Copper Co., clearly demonstrates the process on a broad and liberal basis:

(1) $xCuNiS + 3xCuCl_2 = 2\,xCu_2Cl_2 + xNiCl_2 + xS$
(1a) $CuS - CuCl_2 = Cu_2Cl_2 + S$
(1b) $NiS + 2CuCl_2 = Cu_2Cl_2 + NiCl_2 + S$
(2) $Cu + Ni$ (copper-nickel alloy) $+ 3CuCl_2 = 2Cu_2Cl_2 + NiCl_2$
(3) $Cu + CuCl_2 = Cu_2Cl_2$
(4) $Ni + 2CuCl_2 = Cu_2Cl_2 + NiCl_2$
(5) $2CuNi + 6Cl = Cu_2Cl_2 + 2NiCl_2$
(6) $Ag_2S + 2CuCl_2 = Cu_2Cl_2 + 2AgCl + S$
(7) $FeS + 2CuCl_2 = Cu_2Cl_2 + FeCl_2 + S$
(7a) $CuO + 2HCl = CuCl_2 + H_2O$
(7b) $NiO + 2HCl = NiCl_2 + H_2O$

The above reactions which proceed during leaching take place in an acid, alkali or alkaline earth chloride solution, such as salt or calcium chloride. The purification reactions are the following:

(8) $2AgCl + 2Cu = Cu_2Cl_2 + 2Ag$
(9) $2FeCl_2 + Cl_2 = Fe2Cl_6$
(10) $Fe_2Cl_6 + 6NaOH$ or $3Ca(OH)_2 = Fe_2(OH)_6 + 6NaCl$ or $3CaCl_2$

The reactions taking place during the electrolysis,

(11) $Cu_2Cl_2.NiCl_2 +$ current $= 2Cu + Cl_2 + NiCl_2$, with secondary action on the anode.
(12) $Cu_2Cl_2 + Cl_2 = 2CuCl_2$
(13) $NiCl_2 +$ current $= Ni + Cl_2$

If the production of copper and nickel restricts itself to a refining proposition using soluble metal-bearing anodes we have

(14) $Cu_2Cl_2.NiCl_2 +$ current $+$ CuNi anode $= 2Cu + Cu_2Cl_2.NiCl_2$
(15) $Cu_2Cl_2.NiCl_2 +$ current $+$ Ni anode $= 2Cu + 2NiCl_2$
(16) $NiCl_2 +$ current $+$ Ni anode $= Ni + NiCl_2$

In the Browne process we have the following reactions:

(1) $2CuNi + 6Cl = Cu_2Cl_2 + 2NiCl_2$

Refining reaction, that is, electrolyzing with copper-nickel anodes,

(2) $Cu_2Cl_2.NiCl_2 +$ current $+$ CuNi anode $= 2Cu + Cu_2Cl_2.NiCl_2$

Purification reactions,

(3) $Fe_2Cl_6 + NaOH + NiCl_2 = Fe_2(OH)_6 + 6NaCl + NiCl_2$

Nickel electrolysis using insoluble anodes,

(4) $NiCl_2 +$ current $= Ni + 2Cl$.

In comparing Browne's reactions with those of Hoepfner a great similarity is noticeable. This is especially the case in reactions 13, of the Hoepfner process, and 4, of the Browne process. These two single reactions are identical. In fact, the only differences between the two processes are that Mr. Browne uses a more refined grade of raw material in the leaching process, a refining and separation of copper from cuprous chloride and nickel chloride solutions dependent upon soluble anodes, a slightly increased temperature at which electrolysis takes place, and the employment of concrete baths. Further Mr. Browne makes use of porous tile diaphragms in the nickel electrolysis, whereas Hoepfner uses nitrated cotton ducking.

The employment of concrete or cement tanks, together with porous tile diaphragms, presents nothing new in the art of electrometallurgy. Body having employed the same during his electrochemical research work. The historical development of the Hoepfner process and the Browne process clearly proves that there are points of vital economic interest in the electrolytic production and separation of metals from chloride solutions.

It may be here mentioned that the success attained up to the present time in the commercial production of copper, nickel, zinc and chlorine from chloride solutions by the process theoretically worked out by Dr. Hoepfner should be mainly credited to the tireless efforts of Dr. George Wannschaff, the technical head of the Papenburg Actien Gesellschaft für Metallelectrolyse. In 1899 an attempt was made to establish a zinc works in Canada. The Brunner-Mond works in England were operating to advantage, and the zinc bleach plant at Krauschau was nearing completion. The zinc works at Furfurt in Germany were closed, owing to personal difficulties, and not the failure of the process.

The method employed at the Brunner-Mond works for the preparation of zinc chloride solution consists in a roasting of the ore, thereby converting the zinc contents to a state of oxide. The zinc oxide so obtained is treated under a pressure with a solution of calcium chloride and carbonic acid gas, yielding thereby zinc chloride according to the following equation:

$$ZnO + CaCl_2 + CO_2 = ZnCl_2 + CaCO_3$$

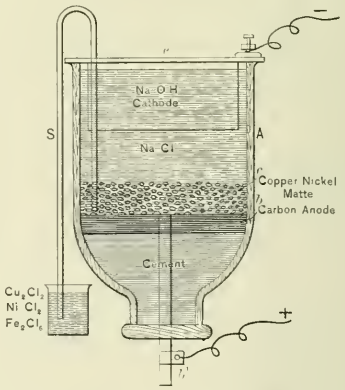



FIG. 4. DEMONSTRATION AT HAMILTON.

The zinc chloride thus obtained after purification, removal of iron, manganese, etc., is subjected to electrolysis in the Hoepfner compartment bath yielding metal and chlorine gas. The metal produced is of exceptional quality, being practically chemically pure. Many samples have shown a zinc contents of 99.98 per cent.

In the works contemplated to be erected in Canada, Dr. Hoepfner wished to introduce a new method for the production of zinc chloride solutions, that is, in the leaching of zinc ores. It is a well-established fact that the success of any electrolytic process depends largely upon the economical and efficient production of the electrolyte used. The simpler the reactions, together with the successive operations, the more valuable the process becomes. The electrolysis in itself is nominal, and from a commercial point of view, a good paying proposition. The scheme proposed by Hoepfner for leaching zinc ores was as follows: The ores were to undergo a preliminary roasting, thereby yielding sulphurous acid and zinc oxide, the sulphurous acid evolved to be absorbed in water. With this aqueous solution of sulphurous acid an extraction of the zinc contents of the ore as sulphite of zinc was to be effected. The zinc sulphite was then to be precipitated as such through the removal of the excess of sulphurous acid.

The crystalline zinc sulphite thus obtained after communing with iron oxide or roasted ore was to undergo a roasting, thus oxidizing it to zinc sulphate. This zinc sulphate was then to be calcined with salt, thereby producing zinc chloride and sodic sulphate. The roasted and converted product was finally to be extracted with water, the zinc chloride and sodic sulphate dissolved out, and the sodic sulphate separated through refrigeration. By this means it is possible to produce a solution of zinc chloride practically free from impurities. The following diagram shows the process in detail.

RAW MATERIAL ZINC, LEAD & SILVER SULPHIDES
MECHANICAL SEPARATION
ZINC SULPHIDE
LEAD SULPHIDE SILVER SULPHIDE ETC.
ROASTING ZINC SULPHIDE
RESIDUES CONTAINING ZINC SULPHIDE, IRON OXIDE ETC.
ZINC OXIDE IRON OXIDE ETC.
SULPHUROUS ACID ABSORPTION
ROASTING WITH SALT, FORMING ZINC CHLORIDE SODIC SULPHATE IRON OXIDE
SEPARATION OF ZINC SULPHITE THROUGH REMOVAL EXCESS SULPHUROUS ACID
LEACHING ZINC OXIDE WITH SULPHUROUS ACID
LEACHING SEPARATION OF ZINC CHLORIDE AND SODIC SULPHATE FROM RESIDUES
ROASTING ZINC SULPHITE WITH IRON OXIDE & SALT, FORMING ZINC CHLORIDE
REBIDUE IRON OXIDE
LEACHING SEPARATION OF ZINC CHLORIDE AND SODIC SULPHATE FROM RESIDUES
REFRIGERATION SEPARATION OF ZINC CHLORIDE FROM SODIC SULPHATE
REBIDUE IRON OXIDE
SODIC SULPHATE
ZINC CHLORIDE
PURIFICATION OF ZINC CHLORIDE
ELECTROLYSIS OF ZINC CHLORIDE
CHLORINE GAS
METALLIC ZINC
BLEACH

DIAGRAM OF HOEPFNER PROCESS.

In 1900 the management of the Canadian Hoepfner Co., having, ever from the start, wished to produce copper and nickel rather than zinc, abandoned the zinc proposition. By previous contracts Dr. Hoepfner had transferred his copper and nickel rights with the exception of producing oxides and salts of these metals, to the Papenburg Actien Gesellschaft. Hoepfner therefore proposed plans, tending only towards the production of copper and nickel oxides and salts from Canadian nickel ores and mattes by his cuprous chloride process, chemically precipitating out the copper, nickel and cobalt as oxides from their respective chloride solutions, instead of electro-depositing the metal.

While Hoepfner wished to introduce a complicated method for the production of a zinc chloride electrolyte, and the production of copper-nickel salts, instead of electrolytic metal, Mr. Frasch wished to substitute caseine diaphragms for nitrated cotton ducking, also to introduce a process for the production of sulphuric anhydride together with another process for the production of corn starch through refrigeration; under these conditions the legitimate production of metals from their chlorides was entirely lost sight of. The dissensions thus produced among the management threatened to attack the commercial practicability of the electrolysis of

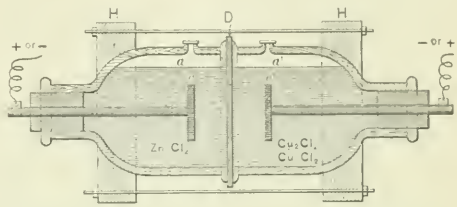



FIG. 5. DEMONSTRATION AT HAMILTON.

chloride solutions, and the deposition of metals therefrom. In order to prevent this, and also to keep up the interest in this particular field of metallurgy, it was at this time shown and demonstrated that in a properly constructed compartment bath two different solutions could be electrolyzed at one and the same time, thereby producing some very interesting results. The production of alkali through the formation of metallic chlorides was also exhibited. The demonstrations made at this time were as follows. They referred to the electrolysis of a salt or brine solution in conjunction with a soluble disintegrating metal-bearing anode.

In Fig. 4 A is a vessel or receptacle containing a carbon bottom *b* provided with electrical connection $b^1$. Crushed copper-

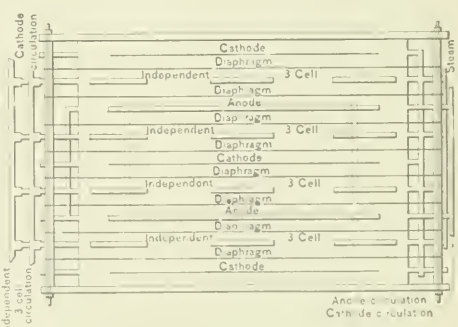



FIG. 6. HOEPFNER THREE-BELL BATH.

nickel-bearing material *c* placed upon the carbon bottom *b*. The vessel was filled with a solution of salt and a cathode *e* suspended therein, a siphon S was so arranged that the electrolyte could be removed from the bottom of the vessel. The reactions taking place were as follows:

(1) $NaCl$ + current = $Na + Cl$
Secondary reaction $Na + H_2O = NaOH + H$

(2) $6Cl + 2CuNi = Cu_2Cl_2 + 2NiCl_2$

(3) $(2CuNi)S + 3Cl_2 = Cu_2Cl_2 + 2NiCl_2 + S$

This demonstration clearly proved the production of alkali with the formation of a copper-nickel chloride solution. In another demonstration (Fig. 5) the apparatus consisted of two tubulated bell jars, whose bottom edges were ground to fit

each other. The two jars, by means of head pieces H and H', with bolts through the same were tightly clamped together, after placing a semi-permeable diaphragm D between them. The jar A contained an electrode $c$ of carbon with an electrolyte of zinc chloride. The jar A' contained an electrode $c'$ of

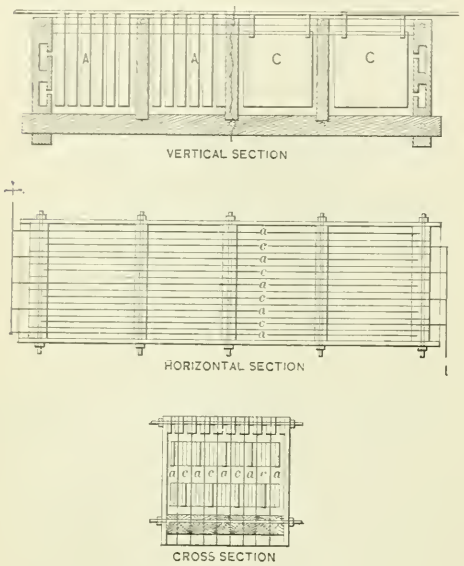



FIG. 7.—HOEPFNER COPPER BATH.

carbon, and an electrolyte of cupric chloride. Electrical connections were made as shown. These experiments showed that it was possible to either produce metallic zinc and chlorine gas or metallic copper and chlorine gas according to the direction of the applied current. Tests were also shown demonstrating

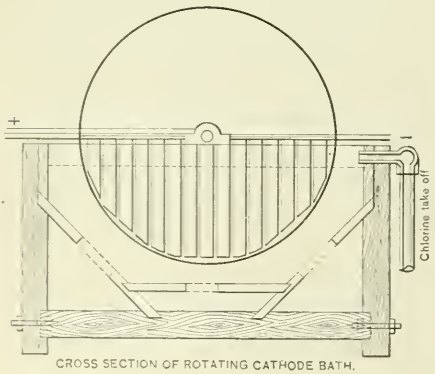



FIG. 8. HOEPFNER NICKEL AND ZINC BATH.

the reversibility of primary or electrochemical current generators when used as energy absorbers.

The above possibilities having been communicated to Dr. Hoepfner by the writer during the latter part of 1899, he, in order to anticipate patents which might be applied for in this direction, viz., covering the electrolysis of a salt solution producing thereby caustic soda together with metallic chlorides, also to circumvent the electrolysis of two separate and distinct electrolytes (compound electrolyte) contained in a unit bath, applied for patents upon a three-cell compartment bath (U. S. Patent filed Sept. 27th, 1899, granted March 12, 1903, serial No. 669, 926). Fig. 6 shows the bath, section 12 of patent specifications reads as follows: "A process which consists in placing a soluble anode of lead or copper in a solution of a salt capable of dissolving same, placing a suitable cathode in a second solution containing a metal of the alkalies, and an oxygen compound of a metal soluble in alkali metal solution, interposing a third solution between the two first mentioned, separating the solutions by suitable diaphragms, mentioned, separating the solutions by suitable diaphragms, passing the current, thereby bringing the anode metal into solution, depositing the cathode metal and forming an alkali hydroxide substantially as set forth."

The practical demonstration, as cited above, had the effect of making converts to the production of metals, especially copper and nickel, and alkali from chloride solutions. The management indorsed the same, and upon September 3, 1900, a demonstration was given by H. A. Frasch, announcing a new and improved discovery in the method of producing metals electrolytically.

The Frasch process, according to his claims, may be briefly summed up as follows. Claim 1 of patent 669,439 reads: An electrolytic bath having an anode extending over its bottom and consisting of a suitable electrical conductor and a body of dis-

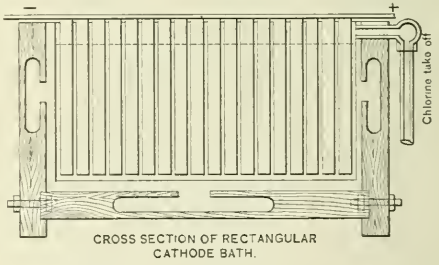



FIG. 9.—HOEPFNER NICKEL AND ZINC BATH.

integrated material containing the metal or metals to be extracted, a superposed layer of sand in immediate contact with the disintegrated material and suitable cathodes. Claim 4 of 669,440 reads: The method of recovering copper and nickel from matte or ore by electrolysis, which consists in disintegrating or pulverizing metal-bearing matte or ore so as to render it free permeable by an electrolyte capable of combining with the metal or metals to be extracted, distributing such mass over the bottom of vessel in which electrolysis is conducted and in connection with electric conductors to constitute an anode, covering said anode with a granular permeable electrically neutral substance, suspending in the electrolyte a number of cathode plates by and upon which the metal is collected and passing an electric current between the anodes and cathodes.

Claim 1 of 669,441 reads: The process of producing alkali and extracting metals from ores and metal-bearing mineral substances, consisting in electrolyzing a solution of salt of an alkali in presence of an anode composed of disintegrated ore or metal-bearing mineral substance, containing the metal to be extracted and a suitable cathode, conducting a supply of a solution of a salt of an alkali, both to the anode and cathode, and displacing the metallic solution obtained at the anode and the solution of caustic alkali produced at the cathode.

Patent 720,235, granted February 10, 1903, is for the method of separating by electrolysis metals from their ores, which

consists in providing an electrolytic bath with a soluble anode composed of comminuted ore bearing the metals to be obtained, circulating successively through a series of such anodes an electrolyte capable of dissolving the metals contained therein and simultaneously circulating the electrolyte obtained from the whole series of anodes past the cathodes of one or more baths, and thereupon depositing the least positive metal, keeping the other metals in solution. Section 7 refers to the method of recovering nickel from nickel-bearing substances consisting in providing a series of electrolytic baths with anodes composed of the comminuted nickel-bearing substances to be treated, electrolyzing the salt of an alkali in the first section of the series of baths, electrodepositing the copper from the electrolyte thereby obtained in the next section of the series of baths, removing by suitable means the iron contained in the electrolyte derived from the whole series of baths, and constantly producing fresh nickel-bearing electrolyte from the anodes of the whole series of baths.

The Frasch process, as shown and demonstrated at Hamilton, Ont., Canada, in September, 1900, may be described as follows. In Fig. 11 A is a vessel which contains a carbon anode B', composed of lengths of carbon rods placed at the bottom with suitable electrical connections. A layer of crushed copper-nickel matte B is placed over the same, the whole is covered

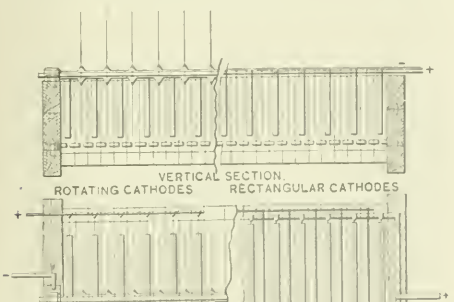



FIG. 10.—HOEPFNER NICKEL AND ZINC BATH

with a layer of sand C. The vessel is filled with a solution of sodium chloride, and suitable cathodes D are suspended in the electrolyte. After allowing the electric current to act for some time, alkali was produced at the cathode, while a solution of copper-nickel chloride was formed at the anodes. This virtually covered the whole of the Frasch demonstration. From the foregoing one could readily infer that a great similarity exists between the Frasch process and the demonstrations which were shown earlier in the season at Hamilton, Canada, for the main purpose of preserving the integrity of a process which consists in the production of metals through the use of their chloride solutions.

The *Eng. & Min. Journal* of September 8, 1900, contains

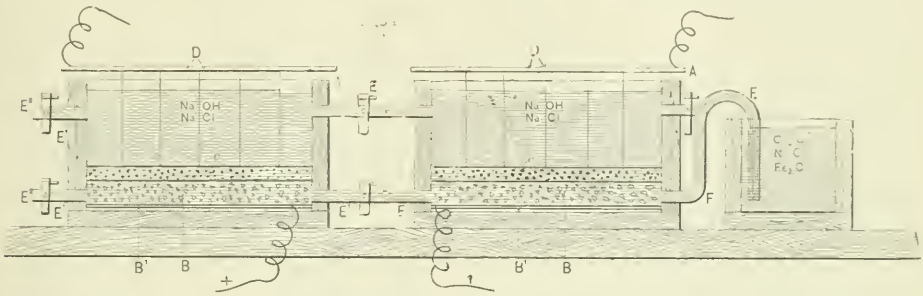



FIG. 11.—FRASCH PROCESS.

an account of the Frasch process, as given by Dr. Jos. Struthers. It was claimed at that time (see this article) that the entire cost of the process would be fully met by the value of the caustic soda and other by-products produced. It was even claimed that the caustic soda could be produced at less cost than by either the Castner-Kellner or the Rhodin process. The developments at Hamilton seemed to indicate that there was something radically wrong, either in the attempt to operate chloride solutions, or in the management, for it did not take long until the Frasch process arrived at a termination. At a special meeting of the board of directors of The Nickel Copper Co., of Ontario, Ltd., called two days after the Frasch demonstration, the fate which has befallen his attempt in electrometallurgy, although the same received the support of many eminent metallurgists, was predicted by the writer, and specific reasons given why the same would result in a failure. The failure of Mr. Frasch's attempt does not in the least affect the commercial value of the production of metals from their respective chloride solutions, provided the same be properly and intelligently handled from a technical standpoint. Owing to the death of the late Dr. Hoepfner, which occurred in November, 1900, the legal proceedings which he instituted against the management have, up to date, not been brought to trial. Since June 1, 1903, the Gesellschaft für Metallelectrolyse mit Beschraenkter Haftung in Siegen, Germany, have, through purchase and otherwise, acquired all of the patents and rights of the late Dr. Hoepfner, and it is to be hoped that the recovery of metals from chloride solutions either through direct production or refining, will shortly be placed in that position in the metallurgical arts to which it is entitled.

## THE SODIUM INDUSTRY IN FRANCE.

By P. LEFEBVRE.

For the extraction of alkali metals and alkaline earth metals there exist, as is well known, numerous patents. The processes best known in France, are the electro-thermic processes of Mr. H. Becker and Mr. A. H. Cowles for extracting sodium and the electrolytic process of Becker, which is used for the same purpose in several electrochemical plants, some of which will soon receive important extensions.

ELECTROLYTIC PROCESS OF H. BECKER.

The electrolyzer of Mr. H. BECKER consists of an iron tank

A, to the bottom of which is attached a large tube *a* closed at its end by a cylinder of insulating material $a^1$ of porcelain or refractory earth. Through the hole in the center of this cylinder the rod *b* passes, at the end of which is fastened the cathode B. The tube *a* is surrounded by a cooling device *h*. The purpose of cooling the tube *a* is to render the electrolyte which is contained therein solid, so as to prevent any leakage between this tube and the plug $a^1$.

The cathode B has a conical surface in order to enable the small particles of metal which are being formed at the cathode to rise perpendicularly upwards to the surface of the bath. The cathode may have, of course, any other form, suitable for this purpose.

The anode C is of annular form and surrounds the cathode entirely. It may consist of one or several pieces, and is made of iron or ferro-nickel. This anode is suspended in the bath by means of one or several bars c which serve as conductors, and which are fixed at its outer surface. The anode never rests on the bottom of the bath, and should not be higher than the cathode.

In the upper part of the apparatus a metallic piece of conical form is provided, which is insulated from the apparatus and serves for collecting the particles of metal which rise to the surface of the electrolyte. The form of this collector D is shown in the illustration. In its central part there is a tube *e* of sufficiently large diameter and of thick walls. This tube *e* is closed at the top by a hinged lid which serves as valve. Attached to this tube is the exit tube *f* which is slightly inclined. At the point where it passes through the wall of the apparatus it is insulated by means of a small tube or ring of porcelain $f^1$.

The diameter of the collector D is somewhat larger than that of the cathode B and smaller than the diameter of the annular anode C. In this way the particles of metal which are deposited on the cathode are all collected by the collector D, while the gases developed at the anode can escape at the side of it. The border *d* of the collector is above the level of the electrolyte, so that the conical surface of the collector D is at its upper surface in contact with air. The purpose is to prevent an abnormal elevation of the temperature.

The collector D is connected in parallel with the negative conductor *g* by means of a suitable resistance, so that only a very small current can pass through this circuit. We have, therefore, in effect only one anode C, but two cathodes B and D, but the arrangement is so that considerably more current passes from the anode C to the cathode B than to the cathode D. The metal which is deposited at the main cathode B rises upwards so quickly that it is not redissolved in the electrolyte, and as soon as it touches the lower surface of the auxiliary cathode D, it becomes electrically a part of the latter, so that it is not attacked again by the bath.

The electrolyte is maintained in a fused condition by the heat developed by the passage of the current. Under these circumstances it is possible to have only the central part of the mass in a fused state, so that the durability of the apparatus is assured.

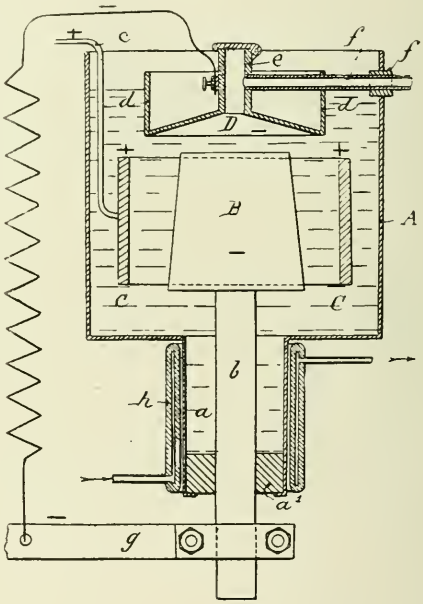
As electrolyte a mixture of caustic soda and carbonate of sodium is used. The metal which flows out of the exit tube is collected in a nearby hermetically closed ingot mould.

The first electrolytic apparatus of H. Becker was installed in 1899 by l'Affinerie Electro-Métallurgique de Bellegarde sur Valserine. At present the Becker sodium process is used by the Usines de Rioupéroux (*Papeterie et Electrochimie*) (Isère), where apparatus for 1,250 amperes are installed. But since it has been decided to install machines for several thousand amperes, and since the results so far obtained are excellent, it has now been resolved to carry out at Rioupéroux the manufacture of sodium on a large scale.

According to the inventor the expenses of the installation of a plant for making 500 kg. of sodium per day are as follows:

| | |
|---|---|
| Ground, 1,200 square meters | $360 |
| Construction of plant and storeroom, 300 square meters | 5,000 |
| Office building, one story, 100 square meters | 3,000 |
| Apparatus (14 electrolyzers of 5,000 amperes, conductors, etc.) | 3,400 |
| Smaller apparatus (ingot moulds, etc.) | 500 |
| Repair shop | 600 |
| Packing and shipping room | 400 |
| Laboratory | 340 |
| Total | $13,600 |

In order to obtain the cost of manufacture we will assume that the plant is situated near a hydro-electric power plant,




BECKER ELECTROLYTIC APPARATUS

from which it receives the current. The annual expenses are estimated as follows:

| | |
|---|---|
| 400 tons of electrolyte (mixture of caustic soda and carbonate of sodium at $4.40 per ton) | $17,600 |
| 500 hp. at $10.00 | 5,000 |
| 18 workingmen on the electrolyzing vats, 6 workingmen for the foundry and ingot moulds, 3 for shipping and 3 extra men; together, 30 men (day of 8 hours, $1.00 per day) | 10,800 |
| One superintendent | 2,400 |
| One foreman | 720 |
| One bookkeeper | 600 |
| Maintenance of apparatus, electrodes, etc. | 3,600 |
| Five per cent interest on capital | 680 |
| Sinking Fund, 10 per cent. | 1,360 |
| Total | $42,760 |

For the production of 180,000 kg. (360 working days) the cost of the kilogram of metal becomes 0.236 cents. This cost does not comprise the wooden and iron boxes for shipping.

### Electrothermic Process of H. Becker for the Manufacture of Chromium, Manganese and Sodium.

The electrothermic process of H. Becker is based on the reduction, by means of carbon, not only of the alkaline oxides or

carbonates, but also of the alkali chromates, tungstates, aluminates, etc. The reduction, by means of carbon, of the alkaline oxides and carbonates has been well known for a long time, but nobody had used the electrical furnace on an industrial scale for this purpose. It had been tried without success for the production of sodium carbide by a method analogous to that of Willson for the preparation of calcium carbide.

By heating in the electric furnace sodium hydrate or sodium carbonate with carbon, no sodium carbide is produced, or, if it should be formed, it is at once again decomposed. In fact what escapes from the furnace are vapors of sodium, carbon oxide, etc., and if an excess of carbon is used it only remains in the furnace as graphite. If a mixture of sodium hydroxide and carbon is heated in a retort furnace like those of Castner and Netto, used a dozen years ago, there is formed sodium, carbonate of sodium, and hydrogen according to the formula $3NaOH + C = Na_2CO_3 + 3H + Na$.

By the Netto process 6 kg. of caustic soda and 1.5 kg. of carbon produced 1 kg. of sodium and 9 kg. containing 60 per cent. of carbonate of soda. The output of the Castner process was still smaller, since to produce 1 kg. of sodium 8.3 kg. of caustic soda were required. In these two processes 8 to 12 kg. of fuel were required per kg. of sodium produced and the wear and tear of the retorts was 1 to 1.2 kg. of cast iron per kilogram of sodium produced.

In the still older process of Sainte-Claire Deville no caustic soda was used, but sodium carbonate. Unfortunately, it was necessary to use retorts of very small diameter to obtain a sufficiently high temperature. The efficiency was low and the expense for fuel was rather considerable. At an elevated temperature, sodium carbonate decomposes according to the formula $Na_2CO_3 + C = Na_2 + CO_2 + CO$.

In the electric furnace a higher temperature is obtained than is necessary, and it is not necessary to use these retorts, which is a great advantage. However, while there is a saving of retorts there is an expense for electrodes. Moreover, electric distillation furnaces for metals as liable to oxidation as sodium are pretty difficult to design, and it is not possible to give them large dimensions, so that the expense for manual labor is high.

In fact, the furnace process of the reduction of caustic soda, and of sodium carbonate presents no special interest, in view of the improvements which have recently been made in the electrolytic process by Becker, Darling, Hulin, etc. The situation is, however, different concerning the furnace reduction, by means of carbon, of the chromates, aluminates, tungstates of sodium, etc.

By heating in an electric distillation furnace, sodium chromate and carbon, one obtains sodium, which distills off and is collected in a condenser, and chromium of excellent quality, which is tapped from the furnace. By treating mixtures of salts, or mixtures of salts and oxides, it is possible to produce alloys. By heating, for instance, sodium chromate and sodium aluminate with a sufficient quantity of reducing agent, an alloy of chromium and aluminium is obtained which remains in the furnace, while sodium distills off. Of course, the oxides or salts which are to be reduced must undergo a preliminary dehydration by calcination.

The most interesting claim of Becker's French patent, 288,274 of April 27, 1899, refers to the reduction in an electric (arc or resistance) distillation furnace, of the chromates, manganates, tungstates, ferrates or other salts, of which the acid radicle is metallic and one of the metals of which is more volatile than the other, by means of carbon or metallic carbides for the purpose of producing simultaneously the metals of the salt, the separation being effected by the sublimation of the one of them. This reduction can be made with or without addition of a material which does not participate in the chemical process, but serves only for making the mass more or less fusible according to the conditions of the case.

The process of H. Becker has been tried with success, and will soon be applied on an industrial scale to the manufacture of chromium, manganese, etc., and of sodium.

To conclude this short note on the processes of Becker, we may notice the recent application of sodium to the refining of iron. Sodium is already used for this purpose in several plants, but it is unfortunately impossible to get at the exact results which have been obtained there. It is certain that sodium can replace aluminium, and it seems possible that it may be again replaced by calcium. The latter metal is experimented with at some extent at present, and Mr. Becker has invented an economical process of manufacture which we hope to describe in the near future.

The principal objection to the use of sodium in metallurgy is that it is, although not dangerous, yet difficult to handle. According to H. Becker, sodium can be used successfully, not only in iron foundries, but for refining copper, zinc, nickel and certain alloys. To make its use easy he proposes to deliver it to the metallurgical plants in boxes made of the same metal, which is to be refined. For iron foundries, for instance, sodium may be delivered in sheet-iron boxes, which may be placed in the tapping hole. The sodium manufacturer, instead of cooling the sodium in ingot moulds, would cool it directly in these boxes.

The quantities of sodium which we believe we can recommend for use in metallurgy are as follows:

For steel, 0.01 to 0.025 per cent; for copper, 0.2 to 0.25 per cent; for brass, 0.2 to 0.25 per cent; for zinc, 0.1 to 0.15 per cent; for nickel, 0.05 to 0.06 per cent.

For copper and nickel one uses at present, in several plants magnesium, the price of which is several times higher than that of sodium, and in certain foreign plants zinc of a bad quality is refined with phosphorous and magnesium.

## THE ROLE OF FORMATION HEATS OF ALLOYS IN ELECTROLYSIS.

By JOSEPH W. RICHARDS.

The abstract in the November number of ELECTROCHEMICAL INDUSTRY, page 547, of the article in the *Journal de Chimie Physique*, by Lonquinine and Schukareff concerning the heat of formation of copper-aluminium alloys, gives rise to the query as to how these values should be utilized by the electrochemist in his calculations of the work done by the current in forming or decomposing alloys.

The values given by Lonquinine and Schukareff are the gram calories evolved in the formation of a gram of each alloy. The first five are exothermic, the last endothermic. (In the abstract, the minus sign was omitted from the last value, — 57.2, and the abstractor was wrong in his presumption that the values given were the kilogram calories per gram molecular weight of alloy formed.)

The correct data, and their derived values, which serve as the starting point for any electrochemical calculations, are as follows:

| | Per Cent of | Molecular | Heats of Formation | |
|---|---|---|---|---|
| Formula | Al | Weights | Per Gram of Alloy | Per Molecular Weight in Grams. |
| $Cu_9Al$ | 12.5 | 217.0 | 123.5 | 26,910 |
| $Cu_5Al$ | 17.6 | 154.3 | 137.0 | 21,278 |
| $Cu_3Al_2$ | 22.1 | 245.0 | 71.0 | 17,395 |
| $CuAl$ | 20.9 | 90.7 | 20.8 | 1,887 |
| $Cu_2Al_3$ | 39.0 | 208.5 | 48.0 | 10,106 |
| $CuAl_2$ | 46.0 | 117.8 | — 57.2 | — 6,738 |

None of these quantities, however, are directly applicable to electrochemical calculations, because they do not concern the chemical equivalent weights (deposited by 96,540 coulombs) of the aluminium, or copper, or alloy concerned. The copper may be in or pass into the electrolyte as a monad or dyad, the aluminium as a triad. Therefore, the formula of each alloy may represent, electrolytically, the following number of equivalents of the respective elements:

| Formula | $Cu_x$ | $Cu_x$ | $Al_y'''$ | $Cu_x + Al_y'''$ | $Cu_x'' + Al_y'''$ |
|---|---|---|---|---|---|
| Cu Al ..... | 6 | 3 | 3 | 9 | 6 |
| $Cu_2Al$ ..... | 4 | 2 | 3 | 7 | 5 |
| $Cu_2Al_2$ ..... | 6 | 3 | 6 | 12 | 9 |
| Cu Al ..... | 2 | 1 | 3 | 5 | 4 |
| $Cu_2Al_3$ ..... | 4 | 2 | 9 | 13 | 11 |
| $Cu Al_2$ ..... | 2 | 1 | 6 | 8 | 7 |

It follows from this, that the calories concerned in the solution or deposition of one of the above alloys, reckoned per 96,540 coulombs of current flowing, or one chemical equivalent concerned, varies, according to which ingredient of the alloy is the one dissolved or deposited, or whether the alloy, as a whole, is dissolved or deposited. The quantity required may be obtained by dividing the molecular heats of formation by the chemical equivalents concerned, as classified in the preceding table. We thus obtain the following table of heats *absorbed*, let us say, per 96,540 coulombs passing, under each of the five possible cases already classified, when the alloys are corroded:

I. When Cu only is dissolved, going into solution as cuprous salt.

II. When Cu only is dissolved, going into solution as cupric salt.

III. When Al only is dissolved.

IV. When the whole alloy is dissolved, the Cu dissolving as cuprous salt.

V. When the whole alloy is dissolved, the Cu dissolving as cupric salt.

| Alloy attacked. | I. | II. | III. | IV. | V. |
|---|---|---|---|---|---|
| $Cu_2Al$ ..... | 4,485 | 8,970 | 8,970 | 2,990 | 4,485 |
| $Cu_2Al$ ..... | 5,320 | 10,640 | 7,093 | 3,040 | 4,258 |
| $Cu_2Al_2$ ..... | 2,900 | 5,800 | 2,900 | 1,450 | 1,835 |
| Cu Al ..... | 943 | 1,887 | 629 | 377 | 472 |
| $Cu_2Al_3$ ..... | 2,549 | 5,098 | 1,133 | 784 | 927 |
| $Cu Al_2$ ..... | — 3,369 | — 6,738 | — 1,123 | — 842 | — 963 |

It will be noted that the heat absorbed in the decomposition of the last alloy is negative, i. e., heat is evolved in its decomposition. The above values are heats absorbed in the corrosion and decomposition of the alloys. For formation of the alloys, heat will be evolved, according to the values of the above table, according to the ingredient which is deposited from the electrolyte.

All these heats, as given above, are directly convertible into voltage generated or absorbed, by dividing by the thermochemical equivalent of one volt, viz. 23,040 calories.

The principles involved in the above calculations are directly applicable to all cases of formation or decomposition, electrolytically, of alloys in general, including amalgams. The principle is well known where only one ingredient is deposited or dissolved, as in the formation and decomposition of sodium amalgam, but the above calculations cover the case also of *both* ingredients being simultaneously deposited or dissolved.

Metallurgical Laboratory,
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## KJELLIN'S ELECTRIC FURNACE AT GYSINGE, SWEDEN, FOR THE MANUFACTURE OF STEEL.

By Frank C. Perkins.

The accompanying illustration, Fig. 1, shows the top of the Kjellin electric furnace at Gysinge, in Sweden, about to be charged, while Fig. 2 shows the side of the furnace with liquid steel issuing from the furnace, and drawing, Fig. 3, shows the details of construction of the furnace.

It is held by F. A. Kjellin that in resistance furnaces with electrodes the steel very easily takes up the impurities from the electrodes consumed, and the cost of the electrodes increases the expense of the output, while the carbonic oxide resulting from the oxidation of the electrodes has a very bad influence by preventing the steel from giving off the carbonic oxide dissolved in it.

The steel can be more uniformly heated by passing an electric current of many amperes through the steel and using the heat evolved by the resistance of the steel for smelting. Kjellin states that as the resistance of the metals when molten is comparatively low, the currents used must be so great that the copper cables have a section at least as great

KJELLIN ELECTRIC STEEL FURNACE.

as that of the steel in the furnace. The Swedish inventor, De Laval, tried to avoid these difficulties by using molten slag instead of steel as resistance in his furnace, but it is thought the result was not satisfactory.

As the carbon electrodes in furnaces of this kind have high resistance, great losses of tension and power result. Water-

KJELLIN ELECTRIC STEEL FURNACE.

cooled iron electrodes might be used, possibly, but then the magnetic properties of the iron cause new difficulties to arise. In order to get sufficient intensity of current, alternating currents must be used and then the magnetism causes the concentration of the current at the surface of the electrodes (skin effect) and the result is a great loss of power. On account of self-induction the capacity of the electric generator is also diminished.

In May, 1899, in Stockholm, Sweden, Mr. Kjellin proposed to Mr. Benedicks, general manager of the Gysinge Works, to eliminate these difficulties by constructing an electric furnace without electrodes. This was accepted, and the furnaces were built, as shown in Figs. 1 and 2, details of which are indicated in drawing, Fig. 3, which shows the principle of the furnace.

with the coil *d,d*, and the current when passing through the coil excites a varying magnetic flux in the core and this flux induces an alternating electric current in the contents of the furnace chamber.

The operation is, in fact, similar to a step down transformer having a large number of primary turns and a single secondary turn. The steel in the furnace forms only a single

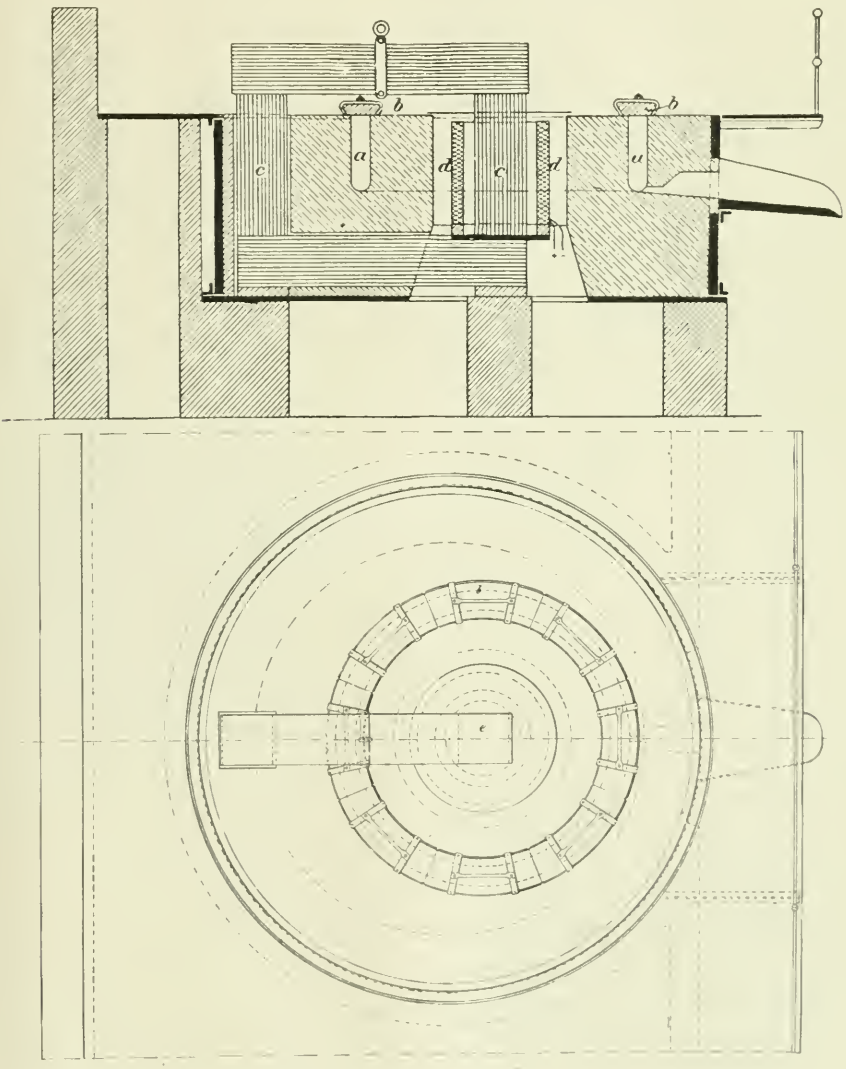



DIAGRAM OF KJELLIN FURNACE

The groove *a,a*, forms the furnace chamber, the sides and bottom of which consists of refractory bricks, and covers *b,b*, are used to close the furnace. A quadrangular iron core C, formed of thin insulated sheets of soft iron, is in the center of the circle formed by the furnace chamber and this is enclosed by a coil *d,d*, of insulated copper wire. The core continues outside the furnace and forms with the furnace chamber the two links of a chain. An alternator is connected

turn round the core, and the current in the steel is then equal to about the primary current in amperes multiplied by the number of turns of wire in the primary coil. The voltage of the current in the steel is of course reduced in the same ratio as the number of amperes are increased. It will thus be seen that it is possible in this way to use an alternating current generator of high tension and yet no transformers are necessary nor copper cables of large sections. The costly

and uneconomical carbon electrodes are also avoided, and yet a heavy current is obtained in the furnace with a low voltage.

The first furnace was installed at Gysinge, Sweden, in February, 1900, and the first ingot was cast on the 18th of March, while it is stated that steel of an excellent quality was produced from the beginning. This solved the problem from a technical point of view but not from a commercial standpoint, for with an electric generator of 78 kilowatts capacity it took twenty-four hours to produce 270 kg. of steel. In November of the same year another furnace was constructed which was able to produce from 600 to 700 kgs. of steel in twenty-four hours with 58 kilowatts, the charges being 100 kg. every three or four hours. On account of the cooling surface of the walls being too great in comparison to the contents of the furnace the output was not satisfactory and the cost of repairs was too high. In August, 1901, a fire destroyed the sulphite pulp mill at Gysinge, Mr. Kjellin states, and then, instead of rebuilding the same, the water power was utilized for steel making by electric smelting and a new plant was constructed for this purpose. This electric steel furnace plant was started in 1902, and since May of that year has worked extremely well. The furnace shown in the illustrations contains 1,800 kg. of steel, 1,000 kg. being drawn off at a time, the remainder being left to keep the current flowing. It produces 4,100 kg. of steel ingots in twenty-four hours when charged with cold materials with 165 kilowatts or 225 electrical hp.

A single phase alternating current generator is employed which generates a current of 3,000 volts pressure. This single phase alternating current is transformed by means of the primary coil and iron core of the furnace into a current of about 30,000 amperes in the steel that forms the secondary circuit.

At Gysinge there is produced only first-class steel from excellent Dannemore pig iron and wrought iron. The method of operation is as follows: When the steel has been drawn off and about 800 kg. left to keep the current flowing, the furnace is charged with pig iron and bar ends as well as steel scrap in such proportions as the experience has proved will give the percentage of carbon wanted. The resulting steel always has less carbon than the material charged, as the pig iron is usually more or less rusty. When the charge has melted and overheated to a proper degree the metal is draw off by tapping in the same way as at the open hearth furnace by a hole in the wall of the furnace.

As will be noted by the illustrations and drawing, the upper part of the Kjellin electric steel furnace is on the same level as the working floor, and the charging is accomplished by simply taking off the covers and putting in the material. As the heat is produced in the steel itself the slag is not so hot as in other steel furnaces, and so the workmen do not suffer from the heat to the same degree.

It is stated that the steel produced is of an uncommonly dense and excellent quality, being homogeneous and unusually tough. It may be easily worked cold when annealed, and is not disposed to crack and warp at hardening as with other kinds of steel. Mr. Kjellin thinks the reason of this is that the steel contains less gaseous matter than other steel, as even small quantities of gases, especially hydrogen, are harmful. He has the following to say in reference to the avoidance of gases in the Kjellin furnace and as to the cost of production of steel ingots:

"By the electric furnace described above the steel has no opportunity of taking up such gases or other impurities, and the quality is also better than that of crucible steel with the same analysis. To make special steels with nickel tungsten or chromium offers no difficulties and the alloys are quite homogeneous. The cost of production depends principally on the efficiency of the furnace and the price of the power.

"At the furnace now in use at Gysinge the losses have been experimentally proved to be 87.5 kilowatt, so that the effective power absorbed by the steel is 165 — 87.5 = 77.5 kilowatts, and as those produce 4,100 kg. of steel in twenty-four hours, one effective kilowatt produces about 53 kg. steel ingots in the same time. Every kilowatt more in the furnace when the size is not altered increases then the output with 53 kg., and we calculate, when we within a few months get a stronger waterwheel, to produce about 6,000 kg. of steel ingots with 200 kilowatts in twenty-four hours. As the absolute cost of labor and repair will be the same those costs for one ton of steel ingots will be about two-thirds of the cost now, and the price of power per ton will also be sensibly diminished.

"The cost of repair, that is, of renewing the lining of the furnace when it is worn out, is now at Gysinge $60.

"From our experience with this furnace, we calculate that a furnace of 736 kilowatts or 1,000 electric hp. will produce 30,000 kg. of steel ingots in twenty-four hours when charged with cold materials. With hot materials the output is much greater. For instance, if 250 kg. of molten pig iron are charged for each ton of steel ingot produced, the output is increased from 30,000 to 36,000 kg. in twenty-four hours with 1,000 electric hp.

"The costs of labor and repairs for such a furnace will in my opinion be less than those of an open hearth furnace of the same size, so that, where power is cheap, there is a possibility of producing a steel competing with the dear crucible steel at a smelting cost not exceeding that of the open hearth furnace."

## DR. HANS GOLDSCHMIDT'S LECTURE ON ALUMINOTHERMICS.

On November 13th, Dr. Hans Goldschmidt, of Essen, Germany, delivered a lecture before the Chemical Society of Columbia University, and a large number of invited guests, on the subject of his thermit process. The lecture hall of the Havemeyer building of Columbia University was crowded, and the perfect success of the experiments shown by Dr. Goldschmidt was highly appreciated by the audience.

Since we have published, in our last issue, an article by Dr. Goldschmidt on the subject of aluminothermics—which contains the most complete and up-to-date information on this subject—our account of his lecture may be brief.

The author defined thermit—in its wider sense—as a mixture of finely granulated aluminium and metallic oxide. The first important discovery in observing the properties of thermit was that, when ignited in one spot, the combustion continues throughout the whole mass without any supply of heat from the outside. The mass is placed in crucibles which are not in contact with any external source of heat, and the combustion when started embraces the whole mass in a very short time. This is the essence of aluminothermics.

The speaker remarked that fifty years ago it was already tried to supply the reducing properties of aluminium, but, without exception, the experimenters heated their compounds externally. The reaction was always so violent that they could operate with only small quantities. The result was with one exception only an aluminium alloy, not a pure metal. This one exception is the method of Messrs. Green and Wahl (Dr. Wahl is now the well-known secretary of the Franklin Institute, of Philadelphia) for producing pure manganese. But Prof. Green heated his crucible from the outside. While the present success of the applications of aluminothermics to various engineering purposes is based on the fact that the reaction will go on after it has once been started at one point.

Dr. Goldschmidt showed as first experiment the ignition of thermit and demonstrated in a second experiment the heat created by this reaction by burning a hole through a one-inch wrought iron plate. The crucible was tapped from the bottom so as to allow the pure iron, which has a temperature of about 3,000° C. (5,400° F.) to run out first. The hole burned through

the iron plate is perfectly smooth-edged; the heat is so concentrated that the plate is well cooled after the reaction.

As an example of the reduction of metallic oxides, the lecturer showed the reaction of nickel thermit. In the processes of producing pure metals free from carbon from their oxides, the slag which covers a regulus of pure metal is utilized as artificial emery on account of its great hardness. It is called corubin. It has also considerable refractory properties which have been utilized in various ways.

The lecturer then discussed at length the process of rail-welding and showed two experiments, one representing the welding together of ordinary running rails, and the other the method for welding the electric third rail. These experiments were made on a commercial scale, and after the lecture the apparatus was broken up and the rail weld was found to be perfect. The author then discussed the application of the thermit process to the repair of broken machinery, and remarked that within the last few months he has supplied thermit in regular ton orders to South Africa for repairing machinery of all kinds in the mining districts which had been damaged in in the late war. It should be of special interest to note that in many cases cast iron has been welded. The most effective work in the way of repairs by thermit has been done in connection with marine engineering, as was described at length in

Hans Goldschmidt

Dr. Goldschmidt's article in our last issue. The next experiment shown by Dr. Goldschmidt was the welding of thermit iron on a steel plate.

The last experiment made by Dr. Goldschmidt, and probably one of the most interesting and most successful ever shown in a lecture on a scientific or engineering subject was the welding together of two pipes. The process is known to our readers so that it is sufficient to say that in a few minutes the weld was completed. The screws were set, the thermit reaction was started, the mould was removed and the weld was found to be perfect. The heat had been concentrated entirely to the welding zone so that a few inches from the same the tubes were at ordinary temperature.

The conclusion of the lecture dealt with the application of thermit in the form of anti-piping thermit to foundry practice This subject was discussed at greater length in Dr. Goldschmidt's articles in our last issue, but it may be mentioned that in connection with ferro-titanium Dr. Goldschmidt called attention to the valuable studies and discoveries made by Mr. Rossi (who also contributed an article on his work to our last issue). Finally, Dr. Goldschmidt showed a number of lantern slide pictures, the greater part of which is known to our readers from the illustrations in our last issue.

We are pleased to illustrate this note by the portrait of Dr. Goldschmidt, and to add a brief sketch of his life. Hans Goldschmidt was born in Berlin, Germany, on January 18, 1861, where his father lived as the proprietor of a tin works, which he had founded in 1847. After having graduated from the "gymnasium" of Altenburg, Hans Goldschmidt studied chemistry, physics and natural science in general at the universities of Berlin, Leipzig, Heidelberg, Strassburg and at the Institute of Technology at Charlottenburg, his principal teachers being A. W. Hofmann, Landolt, Wiedemann, Bunsen, Kundt and Slaby. He received the degree of Ph. D. from the University of Heidelberg in 1886. Since 1887 he is partner of the firm of Theodor Goldschmidt. The works of the company were transferred in 1889 to Essen, since the real estate in Berlin was too expensive to allow necessary extensions of the factory. The works are now conducted by the two brothers, Dr. Karl Goldschmidt and Dr. Hans Goldschmidt, the output being mainly tin and tinsalts. Besides the electrolytic production of tin from tin scraps there is worked a process of producing tin from its ores. Another large product of the works is zinc chloride. In recent years Dr. Hans Goldschmidt has been mainly interested in the development of his ingenious thermit process.

## SCHUCKERT SYSTEM FOR THE ELECTROLYSIS OF WATER.

In the November issue of this journal a rather full abstract was published of a recent article on the production of hydrogen and oxygen by electrolysis, mentioning in some detail apparatus designed by Garuti, Schmidt, and others. The system of Schuckert and Co., of Nürnberg, Germany, has been so successful commercially that a brief description of it may be of interest.

The apparatus, as now manufactured by the Siemens-Schuckert Co., of Berlin, is constructed, with the exception of the copper feed wires and the insulating material, entirely of iron. The cell proper of a unit designed to accommodate 600 amperes, consists of a cast-iron trough approximately twenty-six inches long, by eighteen wide and fourteen deep, requiring, when in operation, about 50 liters of electrolyte In this trough are placed the iron electrodes. These are separated by strips of a

FIG. 1. CELL FOR ELECTROLYSIS OF WATER

good insulating material extending from the top downward about three-fourths the depth of the cell. Between these separating plates and enclosing the electrodes are suspended iron bells, which collect and carry off the gas there generated.

The electrolyte is usually a 20 per cent water solution of

potassium hydrate, although a 15 per cent solution may be used. The concentration is maintained by supplying to the cells an amount of distilled water equal to that decomposed and carried away mechanically by the gas. The loss of potassium hydrate is inappreciable and may be entirely eliminated if the first wash water be used as feed water for the cells.

The units may be connected either in series or parallel with a drop of potential between electrodes of from two and one-half and three volts. The apparatus is operated most economically at a temperature of 70° C. When the cells are protected from radiation, as can be done, for example, by placing them on wooden boxes and packing them in one or two inches of sand, the heat effect of the passing current is sufficient.

The standard types of apparatus are designed to take from 100 to 1,000 amperes, and to furnish gas at a pressure equal to a water column of 70 to 80 mm. For special purposes a cell delivering gas sustaining a water column of 760 mm. may be secured. Both the hydrogen and oxygen are obtained in a relatively pure condition, and the possibility of an explosive mixture is entirely eliminated. The production of normal types of apparatus is about 150 liters of hydrogen and 75 liters of oxygen per kw.-hour when measured over water at atmospheric pressure, and at 20° C.

The attention required for a plant of this kind consists simply in supplying the requisite amount of water to maintain the concentration constant. When in continuous operation the positive electrode, which is made up of a sheet iron plate two millimeters thick, should be replaced at the end of each year.

Attention has already been called to the economy of electrically preparing hydrogen and oxygen, and the many uses to which the gases are now put. The Siemens-Schuckert Co. has installed some very large plants in Europe, one of which is pictured in Fig. 2.

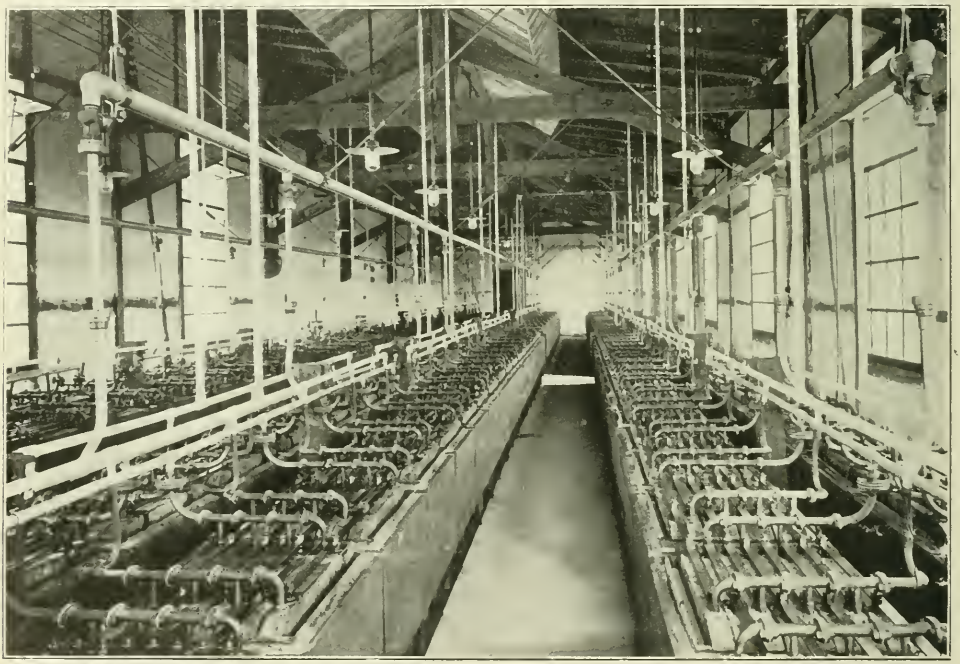


FIG. 2.—LARGE PLANT FOR THE ELECTROLYTIC GENERATION OF HYDROGEN AND OXYGEN.

Laboratory of Industrial Chemistry,
Massachusetts Institute of Technology, Boston.

## THE ELECTRICAL CONDUCTIVITY OF COMMERICAL COPPER.*

By Lawrence Addicks.

Electrical conductivity has come to be a universally accepted measure of the degree of purity of copper for two reasons: First, on account of the enormous quantities of copper used in electrical construction. Secondly, because the conductivity forms a very delicate test of the chemical purity of the metal. Furthermore, a conductivity test may be made upon a wire of suitable dimensions in about three minutes, while a chemical analysis of refined copper is a tedious and correspondingly expensive operation.

Matthiessen's standard (one meter-gramme of pure soft copper at 0° Centigrade = 0.14172 international ohms), has come into very general use, although it is some 3 per cent too low. The fact that the quality of the copper on the market to-day often exceeds by as much as 1 per cent the purest laboratory copper of forty years ago, forms an interesting commentary on the excellence of modern methods.

Conductivity is affected by the physical state of a metal or alloy, as well as by its chemical constitution. Now, in order to obtain the sample of wire upon which a measurement is made, the copper under examination must be subjected to several mechanical processes, and these different variables must be taken into account. It is the purpose of this paper to point out their influence.

First, let us take up the influence of the chemical impurities commonly met with. These consist of oxygen in the form of suboxide of copper, arsenic, antimony, and, in some coppers, bismuth. Small quantities of some other elements may be met with, but those mentioned are the impurities to be looked for in low copper.

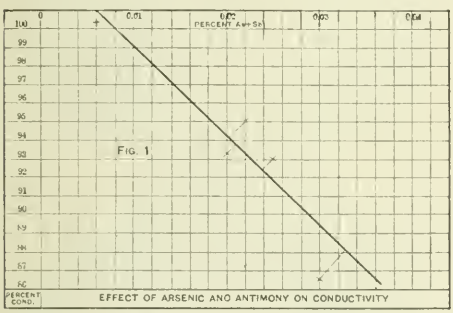
The relation between arsenic or antimony and conductivity

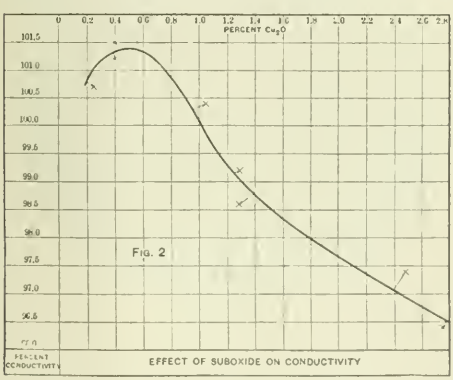
*A paper read before the American Institute of Electrical Engineers.

is shown in Fig. 1. As arsenic and antimony have a very similar influence, the data have been gathered as arsenic plus antimony, thereby greatly simplifying the work. The suboxide of copper is practically constant in all these determinations. The conductivity is stated for annealed samples of wire. It will be noticed that 1/100 per cent of arsenic or antimony lowers the conductivity about 5 per cent.

Fig. 2 shows the relation between suboxide and conductivity in annealed wire. The suboxide has been calculated from the oxygen, itself obtained by subtracting the per cent copper by analysis from 100. The quantity of other impurities present is so small that this is substantially correct. The crest of the curve shows copper "in pitch" or "set" or when sufficient oxygen is retained to keep the impurities as oxides, in which state they are supposed to be less harmful. The possible formation of a carbide or the absorption of hydrocarbon gases from "overpoling" in the refining furnace has also been suggested.

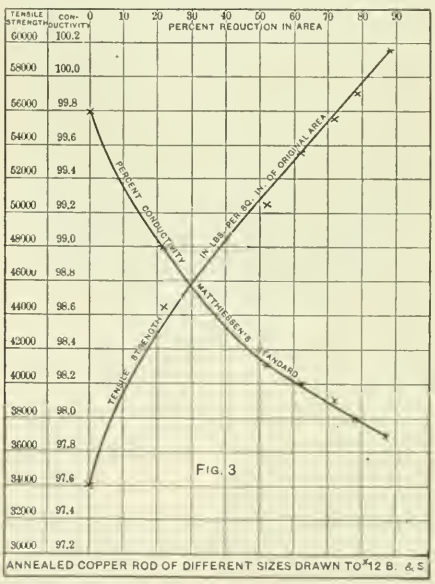
We come now to the physical characteristics and their influence upon the conductivity. We can cause considerable




changes in structure by mechanical operations, and, as would be expected, the conductivity is affected thereby, but by no means as seriously as by arsenic or antimony. The operation most commonly met with is that of wire-drawing—conductivity varies with hardness. In Fig. 3 conductivity and tensile strength are plotted against the percentage reduction in area of a wire rod after annealing, and in Fig. 4 conductivity is plotted directly with tensile strength. It will be seen that the tensile strength varies almost directly as the reduction in area, and that the conductivity drops about 1/10 per cent for every 1,300 pounds gain in tensile strength, a fact which must be taken into account when comparing different samples of hard-drawn wire. Fig. 4 also shows results obtained where a hard-drawn wire is given different degrees of annealing. This ratio, shown by the angle of inclination of the straight line to the axes, is independent, in so far as the writer's investigations have extended, of the actual conductivity of the annealed wire, which is, of course, dependent upon chemical purity.

Fig. 5 shows the effect of temperature in the annealing operation. A 12 B. & S. hard-drawn wire has been heated to various temperatures by being forced to carry currents from zero to a fusing current of about 220 amperes. The actual temperatures were not measured at the time the tests were made. Very roughly the temperature in degrees Fahrenheit will be about ten times the values shown for amperes. In the experiments quoted about 10 feet of wire was put in series with a water rheostat, and the whole shunted around 40 or 50 volts of a 4,000-ampere circuit. The current was adjusted by acidifying

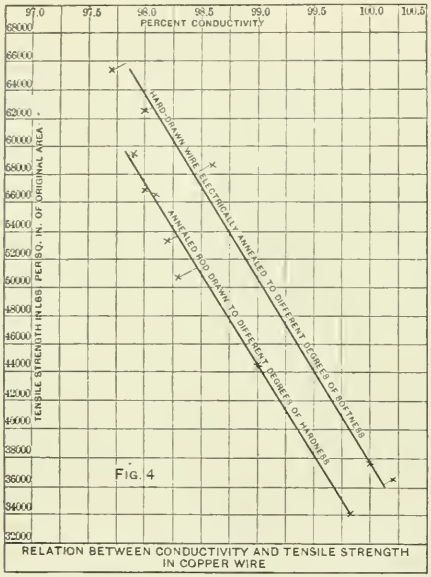



the water in the rheostat, and was left on in each case until it reached a steady value—a matter of about a minute. The time during which the current was on, after this steady heat was reached, seemed to exert no other effect than to increase the shell of scale formed on the wire.

The question at once arises whether the lower conductivity due to overheating is caused by the absorption of oxygen in some way or to a crystalline change. The first idea that suggested itself was to anneal the wire in such a way that oxygen could not attack it. Handling white-hot wire of the length needed in an atmosphere of nitrogen proved somewhat troublesome, however, and was left as a last resort. Silver-plated wire was tried, but the plating would not stand the temperature. Finally the problem was attacked in two different ways. First, samples of burned wire were immersed in dilute nitric acid until the diameter was considerably reduced and then measured for conductivity. No appreciable difference was found, showing that any chemical change was at least uniform throughout the wire. Secondly, samples of burned wire were drawn to a smaller size, reannealed properly and then tested. The original wire, when properly annealed showed 100.4 per cent conductivity; when burned for the test, 98.1 per cent; and when drawn down and reannealed properly, 100.5 per cent. These results show the change to be of a physical, not chemical nature.

Figs. 6, 7 and 8 are micro-photographs of copper samples which have been polished and etched in 50 per cent aqua regia for about thirty seconds. The magnification and the size of rod

from which the samples have been cut are the same in each case. Fig. 6 shows good copper in "set," having a conductivity, when drawn and annealed, of 99.7 per cent. Pure metals when cast crystallize on cooling into irregular grains the size and distribution of which depend largely upon the size of casting and rate of cooling. When small quantities of impurities are present they form a matrix of what is probably an eutectic alloy of the metal and the impurities, in which the grains of pure metal are set. This is the case with the sample under discussion, where the total impurities amount to about one-tenth per cent. Each of these grains is made up of smaller crystals, the cleavage being in different directions in grains. Fig. 7 shows a

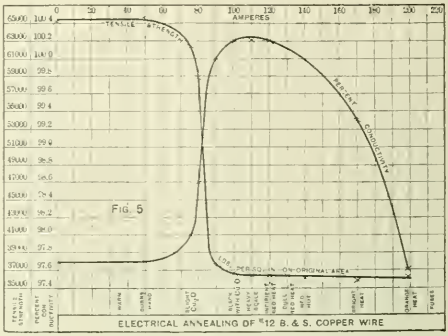



copper low enough in pitch to give trouble at the drawbench. It is the lowest of the series of points on Fig. 2 and runs 96.4 per cent annealed. The change in structure is at once apparent and accounts for the brittleness developed.

When copper is rolled and drawn, this granular structure is broken down, a fine fibre resulting. Fig. 8 shows a sample of trolley wire which has been heated over a gas-blast to a bright heat. It shows a partial return to the crystalline state, the matter surface in places having the same appearance as a hard-drawn sample as far as fibre is concerned. This explains the lowering of conductivity by overheating. The writer has never made measurements of the conductivity of cast copper, but understands from work done at one of the wire mills, that it has been found to run about 3.5 per cent lower than the annealed wire. This is entirely in accord with the data shown above. Copper that has been remelted in the foundry may run but 30 or 40 per cent, due to the absorption of gases.

In cast copper we have a conductivity resulting from the combined conductivities of the pure copper grains and the impure matrix or cement. When this is rolled the structure is broken down and the complex shunt and series circuits rearranged to better advantage. When hard-drawn, the molecular freedom is restrained and more work has to be done in the necessary oscillation of an atom in passing a charge on to its neighbor. In annealing, the wire is brought to a temperature at which the cement is softened and all internal strain is equalized. In burning, crystalline growth is started and reverts the metal to the original condition.

President Arnold, in opening the discussion, remarked that Mr. Addicks' paper puts the matter in concrete shape for elec-




trical engineers, and gives many of the things which some of them have been after when attempting to draw specifications for copper for electrical work. About the only specifications most electrical engineers have been able to draw is that the copper shall have 98 per cent conductivity of pure copper; what that is they had to leave entirely to the manufacturer.

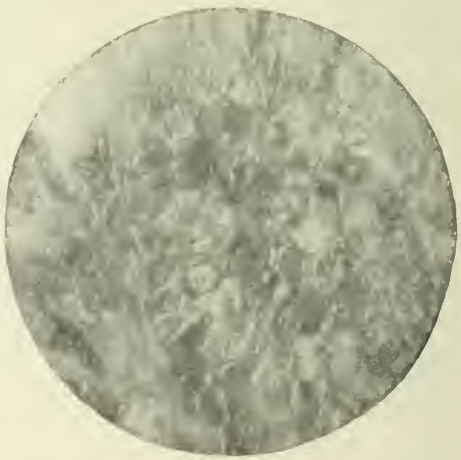


FIG. 6.—GOOD CAST COPPER. (LINEAR MAGNIFICATION 42).

Mr. F. J. Newbury, of Trenton, said at the Roebling Works, in the examination of copper, a method of testing is followed in which the conductivity of the copper expresses to us whether or not it is pure. The conductivity test is the most delicate and most easily applied to find, whether or not copper is in shape for proper working. He then discussed the drawing up of the specifications for copper strands. The speaker took the position that electrical engineers should draw their specification based upon the characteristics of the individual wires of the strand. If such wires are hard-drawn they have a strength of about 60,000 pounds per square inch, and should have a conductivity of 97 per cent, according to Matthiessen's standard. If one strands them, however, the resistance of the strand is not the same as the resistance of a copper wire of equal weight per foot; but the resistance is increased by about 3 per cent, apparently the amount taken up in the twist. In other words, the measured current seems to

follow the individual wires instead of passing freely along a line parallel to the axis of the strand. Similarly, the strength of the strand will be about 90 per cent of the individual wire composing it. Commercial copper of to-day comes very near to "100 per cent conductivity," according to the tables published by the American Institute of Electrical Engineers, and for ordinary cases, is a very fair specification to make.

President ARNOLD saw difficulties in the desire of Mr. Newbury that electrical engineers should base the specifications on the properties of the individual risks. What the engineer wants to know is the net result, so that he can figure the conductivity of the strand complete over a given distance. He wants to know how much copper it will take to get a certain amount of energy over a given distance. He does not wish to be compelled to make the allowance as to what the difference in percentage in conductivity and strength is between straight wires and twisted strands.

FIG. 7.—LOW CAST COPPER. (LINEAR MAGNIFICATION 42).

FIG. 8.—"BURNED" TROLLEY WIRE. (LINEAR MAGNIFICATION 42).

in strength it varies from 52,000 to about 65,000 pounds per square inch, depending upon the reduction in drawing. Sixty-eight thousand pounds is the maximum that can be obtained out of copper wire, and this is only accomplished by careful manipulation. Sixty thousand pounds to the square inch,

# SYNOPSIS OF ARTICLES IN OTHER JOURNALS.

*A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.*

INDUSTRIAL ELECTROCHEMISTRY.

*Ferro Metals and Their Manufacture in the Electric Furnace.*—The *Iron Age* of November 12th contains an article by ROSSI on the ferro metals and their electric manufacture. The author here deals with this subject from a different standpoint than in his article on the same subject, published in the November issue of ELECTROCHEMICAL INDUSTRY. He gives especially pretty full information on the properties and uses of the various ferros. In the first part of his article he discusses the reduction of metallic oxides by carbon and aluminium (see the article in our last issue), in the second part with the properties and uses of ferros. All the ferros are used in a general manner to impart to steel special qualities of hardness, toughness, ductility, strength, etc. The combined use of two or more of these ferro metals may also secure valuable properties for specific industrial applications.

*Ferro-chrome*, free from carbon (less than 1 per cent) or, in some cases, containing 3 to 8 per cent of carbon, is used more especially in the manufacture of shells and tempered products, tool steels and the like—in general, whenever properties of particular hardness are desired; though it secures them at some sacrifice in the toughness of the metal.

*Ferro-tungsten* is very much looked for in the manufacture of tool steel, 9 to 10 per cent tungsten being found in the finished steel, and lately as much as 25 per cent of tungsten is to be introduced into steel. The great weight of tungsten has suggested its use for bullets. Tungsten steel possesses a very peculiar property. When forged red-hot and cooled slowly it presents an extraordinary degree of hardness, but if plunged red-hot in cold water, contrary to what happens with ordinary carbon steel, this hardness gives way to softness.

*Ferro-molybdenum*, used in steel in such quantities as to incorporate in the metal two or three per cent of molybdenum, imparts to it the peculiar property of "air-tempering" or "self-tempering." The author has seen 13-inch shells made of carpenter steel, planed with such molybdenum steel tools, running dry, and which cut ribbons of steel hot enough to be blue without the tool losing its temper. Under certain conditions of heat treatment and quenching it imparts to steel other valuable properties, hardness being a characteristic.

*Ferro-vanadium* appears to communicate to steel properties very much like those secured with nickel, and acts very much also like ferro-titanium. It is a new ferro, not very well known yet. It has been used chiefly experimentally. In the proportion of about 0.50 per cent in the steel, vanadium is said to increase the elastic limit wonderfully. It is very infusible, and in this respect stands next to ferro-titanium. One of the great drawbacks of its use is the scarcity of its ore, which must be highly concentrated, as it occurs sparingly in some rocks and commands a high price. The very lowest price the author has heard quoted for vanadic concentrates, is 50 cents per pound.

*Ferro-silicon* electrically smelted and containing some 25 to 30 per cent silicon and up to 50 per cent, has been much used of late in the manufacture of steel castings. It secures soundness and freedom from blow holes in the castings. It resists atmospheric influences remarkably well whenever the percentage of silicon reaches 25 per cent, or thereabouts, the effect increasing with the percentage of silicon.

*Ferro-manganese* containing 6 per cent manganese or thereabouts loses its magnetic properties, and at 13 to 14 per cent manganese it is practically non-magnetic. It possesses a great resistance to fracture by concussion. The maximum of strength appears to be secured in steel containing some 14 per cent of manganese. Such steels have been used for forgings, car wheels, and crushing and grinding machinery. It is toughened by water quenching, but does not temper in the sense in which the word is generally used.

*Ferro-nickel*, when used for armor plates, boiler plates and structural steel, has stood the tests of a prolonged practice. Some 3 to 5 per cent nickel is generally admitted to be necessary in the finished steel to secure the proper results. As much as 20 to 22 per cent nickel has been proposed for boiler plates. A 30 per cent nickel steel is well adapted for service in salt water, on account of its resistance to corrosive action. Its recognized action upon steel is to secure a high elastic limit and strength, combined with toughness.

The author finally discusses at great length the properties and uses of ferro titanium, and, besides the information given

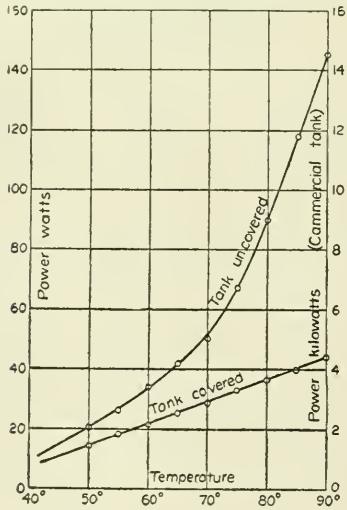



FIG. 1.—RADIATION RUN.

in the article in our November issue, he gives the results of some tests with ferro-titanium.

*Electrolytic Copper Refining.*—In our October issue (page 484) we published an abstract of Dr. W. D. Bancroft's American Electrochemical Society paper on "Electrolytic Copper Refining." We supplement this by the adjoining diagrams, which are reproduced from a paper of Messrs. F. J. Schwab and I. Baum, published in the October number of the *Journal of Physical Chemistry*. It will be remembered that these gentlemen, under the direction of Prof. Bancroft, carried out the experiments on which the conclusions of the paper were based.

Fig. 1 gives the results of the radiation-run. The abscissas represent the temperature in degrees Centigrade at which the electrolysis is carried out. The ordinates represent the electric power required to overcome the loss of heat by radiation and to maintain the temperature constant. It is here assumed that the tanks are heated electrically. The vertical scale at the left hand gives the power in watts, for the small experimental tank. For larger commercial tanks the power must be correspondingly larger, and the vertical scale at the right hand gives the power in kilowatts, required for commercial tanks of the size used by the Baltimore Copper Co. (9 x 2 x ½ feet). From this the figures for other sizes of tanks may be calculated.

It will be seen that at 50° C the uncovered tank needs 42 per cent more power than the covered tank, and 75 per cent more power at 70° C.

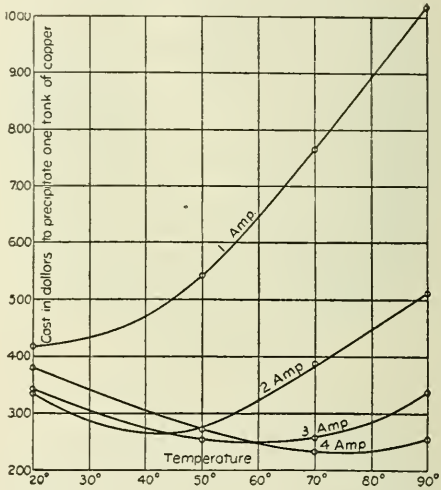



FIG. 2.—RELATION BETWEEN COST AND TEMPERATURE.

To arrive at a conclusion as to the most economical temperature and current density, two sets of curves were plotted which are shown in Fig. 2 and in Fig. 3. Fig. 2 shows the relation between the cost to precipitate one tank of copper and the operating temperature. Fig. 3 shows the relation between the cost to precipitate one tank of copper and the current density in amperes per square decimeter. All figures on which the calculation of these curves is based were already given in our last issue. But it may here again be emphasized that in the cost of precipitating one tank of copper only three items are included: the cost of depositing, the cost of heating, and the interest on copper.

*Electroplating Upon and with Aluminium.*—In our January issue an article was published by Burgess and Hambuechen, in which the problems of electroplating upon aluminium and electroplating with aluminium were discussed. Two articles giving interesting information on these subjects were recently published in other journals. The one by A. Fischer deals with the electrodeposition upon aluminium. He remarks that in many cases it is a difficult matter to obtain a sound and adherent film of some foreign metal by electrodeposition upon ordinary aluminium. Various methods of procedure and numerous baths have been patented, but these are usually of little value. The porosity and irregular degree of purity possessed by commercial aluminium have also been offered as excuses for the troubles of the plater. The author offers the following suggestions as trustworthy: Coatings of copper, silver, nickel, zinc, and tin may be obtained directly upon aluminium; but films of gold, "brass," and arsenic are best applied upon substrata of copper, nickel, or silver. Aluminium coated with copper or silver can be "oxidized," and there will be no danger of the deposit coming off; but the use of hot liquids, and more particularly of hot solutions of alkali sulphites, must be

avoided, or the deposit may blister. If the aluminium has been tarnished by exposure to air, it should be cleaned by the process recommended by the Neuhausen factory. The articles are immersed for 15 seconds in a 10 per cent solution of caustic soda, which has been saturated with common salt, taken out, washed, rubbed with powdered pumice, dipped for another 20 seconds, treated with a German silver scratch-brush and dried. Aluminium containing copper should be dipped in nitric acid, or cleaned by heating. Before immersion in the electrodepositing bath the goods should be well cleaned with a bristle-brush and pumice. For coppering, the old bath, containing 100 grams of copper sulphate and 60 grams of nitric acid (sp. gr. about 1.3) dissolved in 1 liter of water works perfectly. A cyanide copper bath cannot be used, because it seriously attacks aluminium. The current density should be $ND_{100} = 1$ to 1.7 amperes, and the voltage 0.5 to 1.0. For silvering, Neesen's process is good. The aluminium articles are momentarily dipped in hot nitric acid, washed in water, soaked for a few minutes in 10 or 15 per cent caustic soda or potash, then put without washing into a solution containing 5 grams of mercuric chloride per liter, rinsed, dipped again in the alkali, and finally without rinsing put directly into the cyanide silver bath. A somewhat high pressure (about 2 volts) should be em-

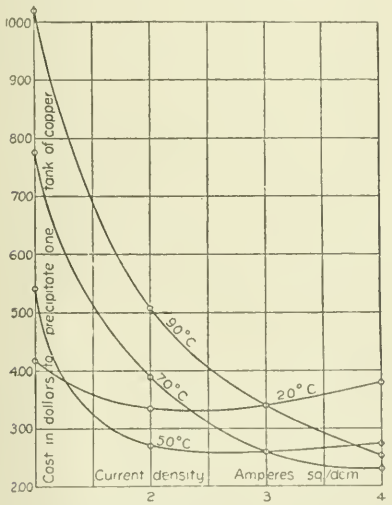



FIG. 3. RELATION BETWEEN COST AND CURRENT DENSITY.

ployed at first. The deposit of silver adheres well, may be scratch-brushed and bears burnishing with steel and bloodstone. The nickel bath should contain nickel sulphate, 50 grams; ammonium chloride, 30 grams; water, 1 liter. Current $ND_{100} = 0.1$ to 0.15 ampere. In two or three hours the deposit is thick enough to bear polishing with oil and whiting. For tin the bath would be sodium pyrophosphate, 20 grams; fused stannous chloride, 8 grams; water, 1 liter. The voltage should be between 2 and 3. The film can be polished by scratch-brushing. For zinc the bath may be zinc sulphate, 180 grams; dry sodium sulphate, 50 grams; water, 1 liter. Voltage = 4. Many varieties of "magnalium" can also be coated by the methods described above. This note is taken from the London *Electrical Rev.*, October 30, the original article having been published in the *Chemiker Zeitung*.

In the November issue of the *American Electrician*, F. A. McDERMOTT describes the following method which enabled him to plate with aluminium. He has also sent us some special information. It is well known that this problem has been attacked by very many experimenters, so that McDermott's method should be of interest, although he does not claim that this process is commercially practicable or even experimentally satisfactory. But he claims that by this method he can deposit aluminium from an aqueous solution upon copper, brass and iron, and probably other metals. A strong solution is made of ordinary copper sulphate, $CuSO_4.5H_2O$, and from this the copper is completely precipitated by an excess of metallic aluminium, either with or without the aid of heat. Hydrogen is evolved during the precipitation, the reaction appearing to be $3CuSO_4.5H_2O + 4Al = Al_2(SO_4)_3.Al_2O_3 + 3Cu + 6H + 2H_2O$. The clear solution remaining after the copper and impurities have been filtered off appears to be a solution of a basic sulphate of aluminium. The liquid has a bitter, alum-like taste, and is quite colorless. This is the solution from which the aluminium is deposited.

The article to be plated is thoroughly cleaned in the usual manner, and is, of course, made the cathode of the electrolytic cell. The anode is a plate of aluminium. One Grenet or Fuller cell furnishes ample voltage. The deposit obtained is of a dull lead color, which, however, changes to the ordinary appearance of polished aluminium under the burnisher. Hydrogen is evolved at the cathode during the passage of the current and another gas, presumably oxygen, appears at the anode. Both gases adhere to, and will eventually cover, the respective plates, unless removed by tapping or otherwise. The solution is an extremely poor conductor, and only a small current can be passed. The current density at which satisfactory deposition will take place seems fairly large, though he has made no definite measurement of it. If too strong a current is used, the deposit will be a non-adherent impalpable powder, or the hydroxide; if too weak, the deposit will be crystalline or granular, and will take place only in spots. He has never tried warming the solution, for, though this might increase its conductivity, it seems probable that it will cause the deposited metal to decompose the water. After having been used for some time the solution gives out, refusing to deposit the metal in any form save the hydroxide, acting in the same manner as a solution of the normal sulphate. Upon standing unused, the liquid precipitates the hydroxide and becomes unfit for use. The anode is corroded very unevenly, an effect presumably due to impurities.

## THEORETICAL AND EXPERIMENTAL.

*Solubility of Magnesium Carbonate in Aqueous Solutions of Certain Electrolytes.*—Under this title F. K. CAMERON and A. SEIDELL, publish in the *Jour. of Phys. Chem.*, November, the results of an experimental investigation which are summed up as follows: When appreciable quantities of carbon dioxide are present in the vapor phase in contact with solid magnesium carbonate and solutions of other salts, there is a marked tendency toward conditions of false equilibria; the usual explanation advanced to account for these observations, that double carbonates are formed, is unsatisfactory. The solubility of magnesium carbonate in solutions of sodium chloride, when in contact with ordinary air, increases with increasing concentration of sodium chloride up to a maximum, and then decreases. The solubility of magnesium carbonate, as the bicarbonate, in solutions of sodium chloride when in contact with an atmosphere containing only carbon dioxide and water vapor at atmospheric pressure, decreases regularly with increasing concentration with respect to sodium chloride, this appears to be a real exception to the hypothesis of electrolytic dissociation for which no explanations based upon that hypothesis can be offered. The solubility of magnesium carbonate in solutions of sodium sulphate, in contact with an atmosphere containing only carbon dioxide and water, increases slightly and then decreases with increasing concentrations of sodium sulphate. In contact with an atmosphere free from carbon dioxide, the solubility of magnesium carbonate increases to a maximum, and then decreases, with increasing concentration of sodium chloride; it increases regularly with increasing con-

centration with respect to either sodium sulphate or sodium carbonate. The solubility of magnesium carbonate in solutions of sodium sulphate, in contact with an atmosphere free from carbon dioxide, appears to decrease with increasing temperature. The solubility curve for magnesium carbonate in solutions of sodium carbonate is not in apparent accord with the theory of electrolytic dissociation.

*Theory of Colloidal Solutions.*—In an article on this subject, published in the *Comptes Rendus,* October 12, and abstracted in the London *Electrician,* October 30, Perrin puts up the theory that every colloidal solution is made up of granules, which are invisible in the microscope, but much more bulky than the molecules, since they diffuse light considerably, and which are charged electrically, since they follow the lines of force in an electric field. The difficulty in the way of this conception lies in understanding why the larger granules do not absorb the smaller ones, as in rain clouds, how the granules can grow and diminish reversibly with the temperature, and how, at a certain limit, an irreversible coagulation can set in, especially under the influence of polyvalent ions. To account for the stable equilibrium, the author supposes that the surface tension and cohesion which lead to the formation of granules are counteracted by the electrification which acts in a dissociating sense, and that at a certain point these two opposing forces are in equilibrium. The author traces the development of a granule from the first conglomeration of atoms to the time when it contains two similar electrons which tend to produce a "segmentation" of the granule by their mutual repulsion. When the granule becomes very large, or when polyvalent ions are present, the chances are overwhelmingly in favor of an equal quantity of both electricities, in which case the granule becomes an electric doublet, and there is nothing to counteract the tendency to coagulate.

*Chemical Apparatus Made from Fused Quartz.*—A paper by H. Heraeus is published in the *Zeit. f. Elektrochemie,* October 22, giving a history of the subject, and a summary of the author's achievements in this line. It is now possible to make any apparatus from fused quartz which can be made by the glass-blower from ordinary glass before the lamp. But the price of quartz apparatus is still comparatively high. The chemical and physical properties of quartz apparatus are discussed at some length. Quartz apparatus is not attacked by water, acids and salt solutions, but by alkaline liquids, and at high temperature by any oxide: it is not affected by rapid changes of temperature. Optically it is perfectly transparent to the ultraviolet part of the spectrum. For this reason interesting results may be expected from experiments with vacuum tubes, made from quartz.

*Rotating Cathode for the Electrolytic Determination of Metals.*—With reference to the recent work of Gooth and Medway, an improved apparatus for the electrolytic determination of metals with the aid of a rotating cathode is described by E. S. Shepherd in the *Journal of Phys. Chem.,* November. The novelty lies in the arrangement and, besides the rapidity of the test, its chief advantage is said to be a saving of at least 75 per cent in the weight of platinum.

*Course in Electrochemistry.*—In the *School of Mines Quarterly,* July, Tucker gives some laboratory notes on exercises in practical electrochemistry, which were prepared for use in the electrical engineering department of Columbia University, to give the students familiarity in the practice of electrochemistry, and particularly in the use of the electric furnace. General instructions are given for the following exercises, some of the notes being illustrated by diagrams: Working of a copper liquid containing arsenic; electrolysis of salt solution with the use of a diaphragm; electrolysis of fused lead chloride; preparation of calcium carbide; laboratory experiments illustrating the principles of the Cowles process of making aluminium bronze, of the Acheson process for making carborundum, of the Hall process for making aluminium, and of the Moissan method of making metallic chromium.

### Primary and Storage Batteries.

*Electricity Direct from Carbon.*—A summary of the present state of the problem of converting chemical energy of burning carbon directly into electricity is given by Lorenz in *Mitteil. d. Phys. Ges. Zürich,* No. 5 (abstracted in the London *Electrician,* October 30). Slow combustion involved in the electrolytic process such as in an ordinary voltaic cell suffers under three disadvantages—viz., the slowness of the reaction between carbon and oxygen at ordinary temperatures, the impurity of the carbon, which gives rise to complicated hydrocarbons in solution and the necessity of using the highly-priced conducting forms of carbon instead of ordinary coal. These circumstances lead to the adoption of a gaseous "electrode" consisting of carbon monoxide, as in the cells of Bucherer and Borchers. In these, however, the currents obtained cannot be proved to result from the further oxidation of the carbon monoxide. Indeed, the existence of carbon monoxide ions has yet to be demonstrated. Another, but more indirect way of utilizing the energy of carbon is that suggested by Nernst, in which carbon is used for regenerating other cells, such as a Daniell cell, by the reduction of the zinc sulphate. Another method proposed by Nernst is to heat an accumulator having a negative temperature coefficient until its e. m. f. disappears and then let it cool. Dolezalek has, indeed, obtained an e. m. f. of 0.6 volt between two lead accumulators having a difference of temperature of 90°. The problem is theoretically soluble, but will require much detail work for its final solution.

An interesting application of the principle mentioned above—to use carbon for regenerating the materials of a discharged primary battery, for instance, for reducing the zinc sulphate in a Daniell cell—is made by Jone in his "coal battery," about which some vague notes have repeatedly been published in recent years in the daily and technical press, but which is now described in full in the *Western Electrician,* of November 21. He uses, however, tin instead of zinc for the material of the positive electrode, for the reason that tin can be more easily reduced from its compounds than zinc. The other electrode is carbon and mercuric oxide is used as depolarizer. The electrolyte is a hot aqueous solution of caustic potash.

The cell is contained in a vessel of nickel-plated iron or nickel steel; in the same is placed a cylinder of tin. In the center of the cell a porous carbon cup is suspended which contains a layer of mercuric oxide. During discharge the tin is oxidized to stannous oxide, while the mercuric oxide is reduced to metallic mercury. (The cell thus acts as an "oxygen-lift" cell.) The e. m. f. of the cell is 1.06 volts.

The oxide of tin is reduced back to metallic tin in a reduction furnace, the waste gases from which are utilized to heat the cell. The mercury is changed back to mercuric oxide by first converting it into nitrate by treatment with nitric acid and then breaking the nitrate up by heat into mercuric oxide and nitrous vapors. The nitric acid is then recovered by oxidizing the nitrous vapors in the presence of steam and atmospheric oxygen. Thus, none of the reacting substances are used up except the coal and the oxygen of the air.

The author describes in detail the mechanical arrangements by which all the operations (discharge and regeneration of the substances) are carried on continuously and simultaneously. The efficiency of the whole cycle with an apparatus of several hundred horse-power capacity is claimed to be 66 per cent of the energy of the coal consumed (as against 10 per cent being the efficiency obtained by means of steam engine and dynamo). The author states that he has recently substituted a cheaper substance for mercury; his new depolarizer is reoxidized by atmospheric oxygen directly, so that the use of nitric acid is eliminated; no further details are given concerning this point. While he formerly used stirring apparatus, these are said now to be superfluous. Two opinions on the cell by Dr. Thurliman and Dr. Beyenbach of the Monadnock

School of Assaying, in the city of Chicago, are printed, partly in abstract.

For those who desire to verify the principal facts connected with the battery, the author gives the following directions. They relate, however, only to the discharge of the battery and not to the whole cycle.

A porous carbon cup can be bought ready-made. The cell known as the National No. III., made by the National Carbon Co., in Cleveland, Ohio, contains one. The cell vessel should be of iron, or, better still, nickel-plated iron. The electrolyte is made by dissolving two parts by weight of caustic potash in sticks in one part by weight of water. By keeping the cell at 160° C. and connecting the carbon cup into which are placed several ounces of mercuric oxide, by means of an "underwriter's" or a similar wire with non-combustible insulation, with a rod or plate of metallic tin dipping into the alkali solution, the voltage may be measured, and an idea obtained of the amperage. If the tin is weighed before and after the production of the current, the loss of weight indicates the energy expended in heat units, 118.0 grammes of tin, representing 67,700 small calories (gramme-degrees) if there is not enough alkali to dissolve the stannous oxide formed, and 70,700 small calories if there is enough alkali to dissolve the oxide. By measuring the watt-hours at the same time, the efficiency of the discharge of the cell may be calculated by converting the electrical energy obtained into the equivalent of heat and comparing the calories thus obtained with the calories expended. A small unit of electrical energy, or watt-second, is equal to 0.241 small calorie, as is well known. The efficiency obtained in this manner amounts to about 85 per cent. With a larger cell it is naturally higher. With the model with which the author has been working it is 95 per cent.

*Alkaline Accumulators.*—A general discussion of the advantages of alkaline cells is given by SCHMIDT in *Mitteil. d. Phys. Ges. Zürich* and abstracted in the London *Electrician*, October 30. Their chief merit lies in the fact that, apart from water, no constituent of the electrolyte enters into the reaction, so that a relatively small amount of electrolyte is required and the weight is reduced. The final result of the discharge may be described as a transference of oxygen from one electrode to the other electrode through the medium of water. The author points out that any metals whose oxides are insoluble in alkalies are suitable for electrodes in alkaline accumulators. Such are the ordinary metals cadmium, iron, nickel, copper, mercury and silver. Zinc oxides are soluble in alkalies, but not in alkaline silicates, aluminates or carbonates. Accumulators consisting of two electrodes of the same metal are most disadvantageous, since self-discharge by the accidental deposition of one metal upon the other is avoided. The difficulties encountered are mainly mechanical, and concern the mounting of the oxide in the shape of cohesive and yet porous masses. The oxide has to be prepared beforehand, as is done by Edison in his nickel-iron accumulator, and is contained in small metallic boxes closely packed. The oxide is utilized to a greater extent the nobler the metal. For silver the utilization reaches 100 per cent. The yield of Edison's accumulator is now given as 25 watt-hours per kg., but the efficiency is stated to be less than that of lead accumulators and the price is higher.

MISCELLANEOUS.

*The Influence of Electricity on the Development of Water Powers.*—An interesting paper on this subject was read before the New England Cotton Manufacturers' Association by Dr. F. A. C. PERRINE, and has been printed in pamphlet form by this Association. In view of the increasing tendency of paper and pulp mills and similar concerns, especially in the New England States, to install their own electrolytic plants for making bleaching powder or hypochlorite, the question becomes important whether it is advisable for any mill to have its separate hydro-electric plant. Dr. Perrine remarks that many mills have been located on account of the availability of the valuable water-power and are to-day operating under great disadvantages from their inaccessibility, rendering necessary a heavy teaming bill for the haulage of raw material, finished product and coal. In order to permit an arrangement of the mill which will connect the machinery properly to the water-wheel, it frequently happens that they are located at sites entailing expensive original construction and unsatisfactory internal arrangements; besides, the location along the streams often gives rise to great repair bills in times of flood, and, finally, in such locations neither mills nor tenements are properly situated with reference to the best sanitary conditions.

Dr. Perrine brings forward the idea of the centralized plant, developing power for the use of many cotton mills, as he believes that the manufacture of the power should not be considered one of the provinces of a cotton mill superintendent. In many cases, this means the purchase of power from an altogether independent concern from the mill itself, though in many cases he hopes in the future to see central power plants owned by the cotton mills, precisely as they own their insurance companies to-day, with a separate and efficient management, and with a common interest and aim. Dr. Perrine therefore advocates the development by means of long flumes in large central power stations of as many rapidly-flowing streams as are available; the development of streams that, by reason of their distance from satisfactory factory sites have heretofore been considered unavailable; the increase of size of the power plants, and the uniting under one management as many power plants as possible; as well as the operation under the same management of steam auxiliaries necessary for the development of constant power; the abandonment by the cotton manufacturers, as far as is consistent with present conditions of the generation of power as a part of their regular business, and the placing of this work in the hands of experts who will install the machinery, make the power and deliver it to the mill for the operation of their dynamos, the location of the mills themselves at points adapted entirely to their manufacture, taking into account both the accessibility to railroads and the comfort and convenience of their employees.

On account of limitations of space we have to reserve a larger number of abstracts for our next issue.

# ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

BY GEORGE P. SCHOLL, PH. D.

ELECTRIC FURNACES AND FURNACE PRODUCTS.

*Electric Furnace.*—H. Harmet, St. Etienne, France. Patent 742,315, October 27, 1903. Application filed November 29, 1901.

Harmet's furnace is composed of three parts, a fusion chamber, a reduction chamber and a refining oven. The fusion chamber has a conical shape, widening towards its bottom. The bottom is sloping towards the reduction chamber and inclined electrodes are supported upon it. The fusion of the oxides is mostly caused by the gases coming from the reducing chamber, the function of the electrodes in the fusion chamber being merely to serve as auxiliaries in the production of heat. The reducing part of the apparatus consists essentially in a horizontal furnace, having a vertical charging chamber at the end towards the refining oven. This charging chamber is filled with coke or charcoal, the column of which

rests on the bottom of the reducing oven. The reduction is said to take place as follows: A first layer of metal collects upon the sole of the furnace; on top of this swims a layer of incompletely reduced oxides, more or less mixed with a third layer of slag. The main column of coke rests on the sole of the crucible, but fragments of it are lifted and float upon the mass. The melted oxides discharged from the fusion chamber fall upon this mixture of coke and slag and are reduced under the influence of the high temperature produced by the current, which is introduced through two carbon electrodes. Before the reduced metal or slag can be tapped, they must both pass through the column of highly incandescent carbon, which perfects the reduction. The crucible is provided with openings for tapping the reduced metal and the slag. The former passes into a third crucible of preferably circular cross-section, where it is heated by an electric current introduced through two carbon electrodes, and is refined in a manner analogous to that in the Martin furnace. The specification seems to describe essentially the same method of procedure, as is well known, from Harmet's foreign patents.

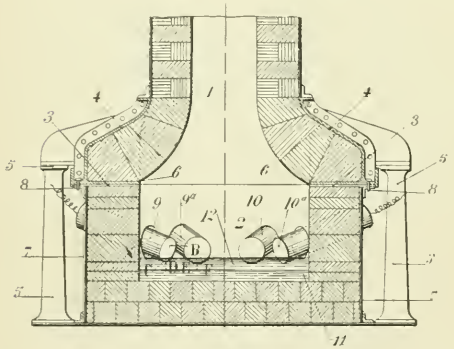


FIG. 1.—HARMET FURNACE.

*Electrometallurgy of Iron and Steel.*—H. Harmet, St Etienne, France. Patent 742,316, October 27, 1903. Application filed originally November 29, 1901. Divided and refiled August 6, 1902.

The specification protects the method of procedure for the electrical smelting of iron and steel outlined above and carried out in the above apparatus.

*Electric Furnace.*—H. Harmet, St. Etienne, France. Patent 742,419, October 27, 1903. Application filed February 20, 1903.

The furnace described in the specification is a modification of the arrangement of the reducer mentioned above in describing the inventor's process. It has the purpose of facilitating the arrangement of a large number of pairs of electrodes, and of preventing the passage of current through the liquid metal. It consists of two portions, 1, 2, which are separated by the joint 3. The upper portion is formed of a metal casing 4, supported by pillars 5, the rib 6 supporting all the masonry. The crucible is formed of a metal casing 7, independent of and not supporting the upper casing. The electrodes are arranged in groups, each group serving for the passage of a separate current; thus, the two electrodes 9, 9a work together, 10, 10a, etc. The metal 11, below the slag 12, is strongly heated by its passage through the latter. All heat is communicated to the slag, which serves as resistance. The electrodes of a current, f. e. 9 and 9a, are given two movements, one axial, allowing the lower end to be placed nearer to, or farther from, the slag, and the other a slight oscillatory movement.

*Electric Furnace.*—F. E. J. Hatch, Greenbay, Wis. Patent 741,333, October 13, 1903. Application filed December 4, 1902.

The furnace consists essentially of a cylinder of metal or other suitable material, lined with firebrick or other refractory materials. A number of straight tubes of porcelain or another highly refractory material pass through the cylinder lining, parallel with the axis and close to the interior surface of the lining. These tubes are open at both ends, and filled with a number of small cylindrical carbon blocks, which serve as conductors of the current. Suitable means are provided at the ends of the tube, to exert pressure upon the carbon blocks and to thus keep them in close proximity to each other. Powdered carbon may also be used instead of the cylindrical blocks. A modified construction is shown, in which the tubes are so disposed as to be flush with the surface of the firebrick lining, and are cut away so as to expose a part of the carbon conductors.

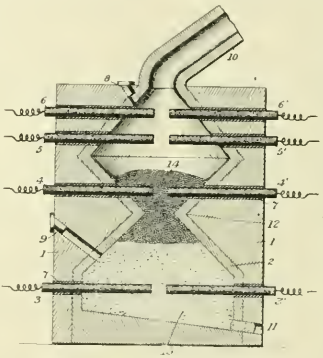


FIG. 2.—FURNACE FOR PRODUCING CHLORIDES OF CARBON.

*Process of Producing Chlorides of Carbon.*—F. J. Machalske, Brooklyn. Patent 742,340, October 27, 1903. Application filed June 18, 1903.

The process is carried out in the apparatus illustrated in Fig. 2. The preferred mode of operation consists in charging a mixture of sodium chloride and silica 13 into the lower part of the furnace. The mixture is then heated by an electric current passing through the electrodes 3, 3', when the sodium chloride melts and the silica reacts with it, liberating the chlorine. The latter rises through a column of coke 14, which is kept in a state of incandescence by the electrodes 4, 4', and forms the various chlorides of carbon, according as the proportions of the ingredients of the charge are varied, or the number of electric arcs in the furnace chamber above the charge. The furnace stack is lined with magnesia brick, and has charging openings 8, 9, a tapping hole 11, and an outlet flue 10. The temperature required for the reaction is stated to be somewhat below 2000° C., an electric current of 500 amperes at sixty volts being sufficient for a furnace of the usual size. Sulphur chloride may be produced simultaneously by adding sulphur to the charge. The upper arcs, above the charge, serve to modify the composition of the chloride of carbon, by reducing them to a lower state, according to the equations: $CCl_4 + C_2 = 2C_2Cl_2$; $CCl_4 + C = C_2Cl_4$. They also serve to bind any uncombined chlorine present in the gaseous carbon compounds.

*Production of Nitrogen Compounds.*—G. de Chalmot, Leaksville, N. C. Patent 741,396, October 13, 1903. Application filed Jan. 23, 1896.

The invention relates to the production of nitrides of metals or metalloids in the electric furnace and the production of ammonia from them. Nitrogen is forced through the incandescent materials, which are mixed with an excess of carbon in order to prevent the resulting molten mass from becoming too fluid and to render it porous. The material which the inventor preferably employs is titanium oxide or a high-grade titaniferous ore. This is pulverized and mixed with a basic oxide, preferably caustic lime, and a carbonaceous material,

preferably coke or charcoal. This mixture is then submitted to the electric arc in a furnace shown in Fig. 3. It consists of a long stack A, which contains in its upper part the furnace chamber B. Electrodes C, C are introduced into the latter. A hopper A with slide E serves to feed the raw material into the furnace. The inventor prefers to introduce the nitrogen in the form of producer gas chiefly a mixture of nitrogen and carbon monoxide. The producer gas is admitted through pipe I. and is drawn through the furnace by means of a suction blower. Openings a a are provided in the lower part of the furnace for passing in superheated steam, which decomposes the nitrides, generating ammonia. The gases pass out of the furnace through perforated pipes b, b, of porcelain or metal, which are arranged to be water-cooled in the latter case. Through openings C in the walls of the furnace, the gases are conducted to the pipe d, which leads them to the purification and ammonia absorption apparatus. The apparatus is constructed for a quasi-continuous running by providing it with a movable bottom g, and the necessary mechanism, shown in the illustration, by which that bottom can be gradually lowered and fresh material brought between the carbons. Other oxides than that of titanium may be used and alumina is stated to have given especially favorable results.

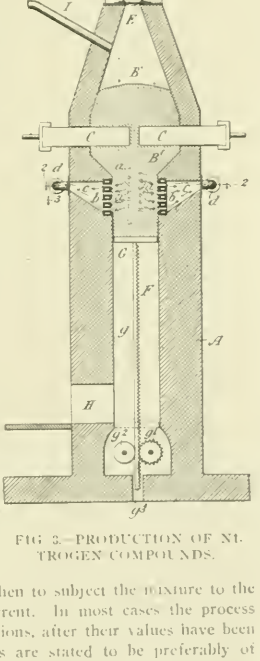


FIG. 3.—PRODUCTION OF NITROGEN COMPOUNDS.

APPARATUS AND PROCESSES FOR THE ELECTROLYTIC PRODUCTION OF METALS AND COMPOUNDS.

*Process of Treating Cyanide Solutions.*—W. H. Davis, Boulder, Col. Patent 741,231, October 13, 1903. Application filed July 3, 1902.

The invention relates to the extraction of gold and silver from ores by the cyanide process. The inventor proposes to add an alkaline hydrate to the contents of the cyanide storage or leaching tanks, and then to subject the mixture to the action of an alternating current. In most cases the process is said to be applied to solutions, after their values have been precipitated. The electrodes are stated to be preferably of lead, and the solution is subjected to an alternating current of a strength predetermined according to the amount of solution in the tank. The inventor states further that the distance apart at which the electrodes are placed is a factor of the cycle of the current, and must likewise be determined for each particular case. The data of the alternating current are specified by the inventor as follows: "The volume of the current used may be from 0.01 to 0.04 amperes per ton of solution, and the voltage in accordance with Ohm's law $\frac{P}{R} = C$ (!). With regard to the number of cycles admissible for ordinary commercial use, from sixty to 120 have been tried and are satisfactory." When the current is applied to the solution, while contained in a solution tank, the hydrates of the metals, such as mercury, copper, arsenic, antimony, iron, aluminium, chromium, manganese, cobalt, nickel and magnesium are said to fall as precipitates to the bottom of the tank, all these metals are stated to have been found by analysis to have been precipitated by the process.

*Process of Treating Ores.*—C. E. Baker and A. W. Burwell, Cleveland, Ohio. Patent 741,439, October 13, 1903. Application filed December 23, 1902.

The process is said to be especially intended for pyritic ores of nickel and copper, like the Sudbury ores. The first step is the chlorination of the ore, which is carried out in a revolving drum, lined with porcelain or lead, through one of the hollow trunnions of which the chlorine is introduced. The ore is crushed to about fifty mesh, and the drum filled one-third with it. A chamber of boiler iron, with an interior covering of asbestos, surrounds the drum, and is provided with an inlet at the bottom, for the purpose of introducing waste products of combustion, which are intended to heat the contents of the drum to about 150° C. Sulphuryl chloride is stated to be evolved under these conditions, which is carried off through the other hollow trunnion of the drum into suitable condensing apparatus. Care should be taken to stop the introduction of chlorine gas the moment all sulphur is removed, in order not to effect the conversion of $FeCl_2$ into $FeCl_3$, which might be driven off with the $S_2Cl_2$. The residual mass is then tested with water to bring the chlorides into solution, and a sulphate or sulphuric acid is added to convert the metallic chlorides into sulphate. It is then proposed to subject the solution to electrolysis, using an electromotive force low enough to deposit only the copper. It is then neutralized and the nickel deposited with a current density insufficient to effect the deposition of iron; previous to the deposition of the nickel, however, it is proposed to add ammonium oxalate or "other salt" to the solution, to convert the nickel sulphate into "such double nickel salt as may be desirable for electrolysis." As a final step it is proposed to electrodeposit the iron remaining in the solution, briquet it and melt it down

*Electrolytic Diaphragm.*—T. L. Roberts, New York. Patent 741,592, October 13, 1903. Application filed March 7, 1903.

The specification describes a diaphragm consisting of glass cloth, the interstices of which are filled with gelatinous material. The glass cloth is woven of very finely spun filaments of glass, a large number of which compose each thread of the warp and woof. The preferred method of treating the diaphragm is to place it into the battery before it is impregnated, and then to fill the compartments on either side with a solution of sodium silicate. The latter is allowed to remain until all the interstices of the diaphragm are filled. It is then removed and a dilute solution of sulphuric or hydrochloric acid put in its place, until, after a little while, the silicate will be gelatinized, after which the acid is removed.

*Electrolytic Decomposition of Alkaline Salts.*—Meyer Wildermann, London, England. Patent 741,864, October 20, 1903. Application filed May 5, 1902.

The cell described in the specification belongs to the mercury type of cells for alkali chloride electrolysis, and several modifications are shown. The first apparatus is a rectangular one, being divided into three compartments by two series of superimposed troughs, fitted with mercury to a certain height. Each trough has at its lower surface a thin rib, which dips into the mercury of the next lower one, thus bringing half of the mercury in the troughs into the centrally arranged anode compartment. Carbon electrodes are introduced into the latter, resting on the bottom of the apparatus. With a previous apparatus the inventor has found difficulty in getting the amalgam of sodium, which was formed in the central compartment, to travel by diffusion into the outer compartments, where it is to be discharged and caustic soda formed. For this reason he proposes in this apparatus to effect the transference of the amalgam, a series of ebonite blades, provided with teeth or projections, which dip into the mercury on the decomposing side of the apparatus and are fastened uprights, which can be given a reciprocating motion. The inventor discharges his amalgam by placing small particles of carbon around which one or more fine pieces of wire have been wound. He states that there is thus produced a num-

bed of small local decomposing cells on the surface of the amalgam, and the decomposition of the alkali metal amalgam proceeds very quickly. The mercury seal in the troughs is preferably seven to ten millimeters deep. The inventor states that he can operate the cells under much more unfavorable conditions than should be allowed in practice, with a current density of twenty-five amperes per square decimeter at a voltage not exceeding 6.5. He finds it practicable to employ in continuous working only from 48 to 60 grams of mercury

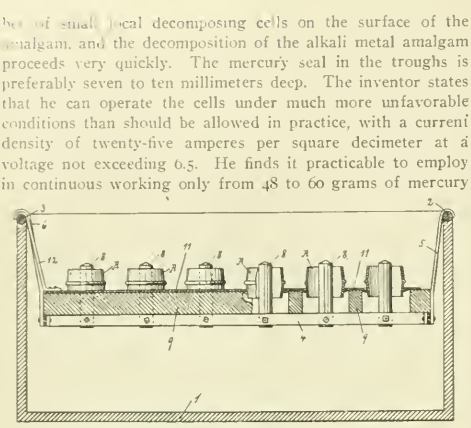


FIG. 4.—APPARATUS FOR ELECTROPLATING.

per ampere. He seems to think that the above is a high current density. As regards the voltage, it is hardly likely that a process using such high voltage for aqueous solutions could compete with the successful processes in use at present.

*Apparatus for Electroplating.*—C. T. Pratt, Frankfort, N. Y. Patent 742,131, October 20, 1903. Application filed July 6, 1903.

The apparatus which is illustrated in cross-section in Fig. 4 is especially designed for the electroplating of slip-nipples with zinc, with the bulk of the deposit on the interior surface. The apparatus consists of a rectangular tank 1, in which is suspended an anode rack 4, constructed out of a number of parallel bars with connecting bars at the ends. The zinc anodes 8 are suitably connected at regular intervals to these bars and project upwards. On top of the anode rack rests a spacing board 9 of insulating material, provided with large holes, which surround the anodes. On top of the board 9 there is arranged a metallic sheet 11, with smaller holes than those in the spacing board. The edges of these holes are preferably notched, so as to form a spring edge, which serves to hold the nipple to be plated, when it is inserted into the hole. The sheet 11 is connected to the anode by means of hanger 12, while the anode rack is in communication with the positive conductor 2 by means of hanger 2. The whole structure is readily accessible for the purpose of replacing or repairing.

*Apparatus for Electroplating.*—A. R. Pritchard, Rochester, N. Y. Patent 741,274, October 13, 1903. Application filed June 23, 1903.

The invention relates to a device for plating parts of sheet metal-ware vessels on one side only. It consists mainly of fastening two of these shapes back to back, with a metal plate between them, which serves at the same time as conductor of the current.

*Electrolytic Reduction of Organic Compounds by Means of Titanium Compounds.*—M. Moest, H. Hertlein, E. Oppermann, Höchst-on-the-Main, Assignors to Farbwerke, vormals Meister, Lucius und Brüning. Patent 742,797, October 27, 1903. Application filed July 14, 1903.

The inventors have found that when a titanic solution, f. i., a solution of titanic sulphate acidified with sulphuric acid, is electrolyzed without a diaphragm, with a lead cathode and platinum anode, the whole of the hydrogen at the cathode is first used to reduce the titanic salt, while the corresponding amount of oxygen escapes at the anode. The yield is first quantitative, then decreases as the proportion of titanous salt increases, and finally no further reduction occurs. If, however, a substance capable of reduction is introduced simultaneously, f. i., finely-divided azo-benzene, then the titanous salt formed at the cathode is at once reoxidized by the conversion of the azo-benzene into bensidene, which is precipitated as sulphate. The organic substance serves as receiver for the electrolytic hydrogen. Thus, the proportion of the titanous salt compared with that of the titanic salt remains very small, so that the yield is favorable, although no diaphragm is used. As a practical application the process is carried out in a vessel lined with lead and serving as cathode. It contains sulphuric acid with any quantity, f. i., two per cent, of titanic sulphate dissolved in it. Any first-class conductor which is not attacked may serve as anode. The circuit is closed, and a concentrated solution of ortho-nitro-para-cresol-ortho- sulphonate of sodium is introduced, with stirring it, at a moderate temperature. The introduction is best regulated in such a manner as to always leave some titano compound in the electrolyte. Part of the amido compound formed is directly precipitated, and the remainder obtained by concentrating the electrolyte. The whole is then filtered and the electrolyte may be used for another operation. The reduction of nitrobenzene to aniline is carried out in the following manner: Fifty liters of hydrochloric acid of 3 per cent strength, containing a solution of about one to two per cent of titanium chloride are introduced into the cathode compartment of a cell, one kilo of nitrobenzene and 600 cc. of alcohol being stirred into it. The anode compartment contains an acidified solution of common salt. Any first-class conductors which are not essentially attacked, may be used as electrodes. The electrolysis is conducted without heating, and with a current density of 3 to 6 amperes per square meter. As soon as somewhat more than the theoretical quantity of current is used, the process is interrupted, and the anilin, which is obtained in excellent yield, is isolated in the usual manner. The reduction of azo-benzene to bensidene and the reduction of quinones are also described.

## Galvanic Cells.

*Electric Battery.* H. Halsey, New York. Patent 735,971, August 11, 1903. Application filed April 18, 1902.

This is another form of the well-known type of battery of this inventor, in which mechanical movement is resorted to for bringing about a continuous circulation of the electrolyte. In the present instance, circulation is maintained by air, which is introduced at the bottom of the containing vessel under pressure. The cell itself drives a motor, which in turn actuates a blower for the purpose of furnishing the necessary air. It is claimed that polarization is prevented in this way.

*Electric Battery.* H. Halsey, New York. Patent 736,248, August 11, 1903. Application filed April 18, 1902. Divided and refiled December 13, 1902.

The present invention provides a receptacle for feeding a depolarizing fluid to a battery electrolyte. It consists essentially of a reservoir having a series of nozzles. In each of these nozzles is contained a core of blotting paper or another absorbent material of high capillarity. This allows the depolarizing liquid to be gradually fed to the electrolyte.

*Electric Battery.* H. Halsey, New York. Patent 737,613, September 1, 1903. Application filed December 6, 1902.

In this specification the inventor describes a new departure in connection with his cells, which contain movable electrodes. He now proposes to seal the cell hermetically and to exhaust the gases from it by an air pump. Outside of the movable electrodes he puts an asbestos diaphragm which has perforations to allow of the circulation of the electrolyte. This at the top is attached to a hollow hanger, which communicates by a pipe with the air pump. He states that "by the use of a porous diaphragm in a partial vacuum, the gases will be carried off more readily from the bottom, as they will be drawn into the interstices of the diaphragm and directly up through it by the exhaust, which will not be strong enough to draw up the liquid."

*Electric Battery.* H. Halsey, New York. Patent 737,614, September 1, 1903. Application filed December 6, 1902.

In the present form of battery provision is made for moving both electrodes. For this purpose they are both made tubular, and one of them placed inside of the other. They are supported upon shafts which pass through the sides of the containing vessel, each of which shafts is in connection with an electric motor, from which it is driven. The power to drive the motor is, of course, as in the other constructions of the inventor, furnished by the battery itself. The cylindrical electrodes move in opposite directions.

MISCELLANEOUS.

*Process of Electrolytically Preparing Lithographic Plates.* O. C. Strecker, Darmstadt, Germany. Patent 737,882, September 1, 1903. Application filed April 19, 1900. Divided and refiled April 19, 1902.

The invention consists in employing electrolysis for the purpose of coating metallic plates with a layer of hygroscopic materials, in order to prepare them for printing purposes. The process is carried out in the following manner: A metallic plate, preferably of zinc or aluminium, but also of copper, nickel or alloys of them with former, is ground, rinsed with water and dried and a lithographic design, the negative of the intended print, is fixed on it. The plate is then gummed with a solution of gum arabic, dried, and the greasy substance is washed out by lithophene, a solution consisting chiefly of asphaltum in benzene or spirits of turpentine. The excess is wiped off and the plate dried; then the gum arabic is washed off the plate with water, and the lithographic design is left on the plate as a layer of asphaltum. After cleaning and correcting the plate, it is ready for the electrolytic process. Electrolysis is either carried out by suspending the plate in an electrolyte and passing the current or by arranging it horizontally, connecting it with the source of electricity, covering it with the electrolyte and then rubbing over it with the other electrode, which in this case consists of a metal plate provided with an insulated handle and faced with a layer of cotton four to five millimeters thick. The plate is subjected to the influence of an alternating current, the intensity of which is 0.1 ampere to 4 square inches, which latter is the size of the electrode opposed to the plate under treatment. The duration of treatment is five to ten minutes, the voltage not exceeding two volts generally, the frequency being about fifty to sixty. The electrolyte may consist of a solution of 3 per cent of a neutral phosphate, sulphate or the like. The passing of the current produces on the printing plate a layer, insoluble in water, which is stated to be probably the oxide or hydroxide of the metals employed. The character of the layer will be either neutral or basic, and as such would be useless for printing purposes, as it would attract the color or ink instead of the water, and cause the printing paper to grease up. The layer must, therefore, be heated with weak acids, or with substances like acid phosphate of ammonia, acid fluoride of ammonia, or silicofluoride of ammonia, the acids of which will form insoluble salts with the metals employed. In the case of a zinc plate the solution consists of ninety parts of water, six parts of gum, two parts of nitrate of ammonia and two parts of silicofluoride of ammonia.

*Method of Cleaning Filters.* T. J. Zoeller, Nashville, Tenn. Patent 736,669, August 18, 1903. Application filed June 7, 1901.

The inventor proposes to apply the electric current for the removal of silt and similar deposits from porous filter plates. The passage of the current gives rise to the formation of gases, which are relied upon to clean the plates. The inventor preferably first connects the positive pole of the battery with the plate to be cleaned, and the oxygen liberated on the application of the current is said to loosen the deposit. The current is then reversed in order to effect the liberation of hydrogen, which, occupying a larger volume, is said to force off or strip the deposit from the plates. After this operation is gone through with, the current is reversed again in order to cause the liberation and occlusion of oxygen in the plates, and to oxidize the organic matter. Alternating current may also be employed.

*Process of Decomposing Water by Electrolysis.* W. F. M. McCarty, Rocky Ridge, Md. Patent 736,868, August 18, 1903. Application filed April 22, 1902.

The inventor proposes to make the water more conductive by the addition of tartrate of potassium, tratrate of sodium, or any of the citrates or other equivalents, and sulphuric acid. The quantity is one pound each of potassium and sodium tartrate, to each ton of 2000 pounds of water, and after these have thoroughly dissolved, sufficient sulphuric acid of 66° Be. is added to make the water a one five-hundredths solution. The apparatus is a very simple one, consisting merely of two tanks connected about at half their height by a pipe. Sheets of platinum are used as electrodes. The tartrates are dissolved first, and the solution run into the electrolytic vessel; the sulphuric acid is then introduced. The following is the inventor's idea of the reactions taking place: "When the salts come into contact with the sulphuric acid, the water at first gives up a portion of its oxygen (!) to form carbonic acid gas, which is allowed to escape. This leaves the water more susceptible to the action of the current (!) which is turned on at the moment of ebullition of the water, caused by the decomposition of the salts on the addition of the acid." A little later he makes the remarkable statement, that the action of the salts, which are added, on the water renders it possible to use a current of much less strength (!) than is required where pure water forms the electrolyte. The apparatus, as shown in the sketch accompanying the specfication, will need a good deal of development before it will be a serious rival of those of Garuti, Schmidt or Schoop. In place of sulphuric acid, tartaric, citric or acetic acid may be used, on paper, but probably not in practice, if the profit from the sale of the gases is not to figure on the wrong side of the cost sheet.

*Apparatus for the Purification of Water.* S. S. Pridham, Newark, N. J. Patent 735,817, August 11, 1903. Application filed July 20, 1901.

The apparatus described in the specification under consideration consists of a rectangular wooden tank, provided on the inner surfaces of the longitudinal sides with cleats, between which the electrodes are arranged, the cathodes and anodes being disposed alternately. The electrodes are of such size, that they fill out the cross section of the tank and rest on the bottom. Communication between the various compartments thus formed is secured by means of rectangular openings cut out at one side of the tank from the anodes, and at the other side from the cathodes. The electrolyte, therefore, has to pursue a winding path on its travel through the apparatus. The arrangement of electrical connections for the apparatus is described in detail. The invention seems to consist primarily in a novel electrode, consisting of an alloy of magnesium and aluminium, the best results being obtained by the employment of an alloy of about 95 per cent magnesium and 5 per cent of aluminium. The apparatus is also intended for the defecation of sewage.

*Process of Generating Electricity.* J. H. Reid, East Orange, N. J. Patent 736,016, August 11, 1903. Application filed May 17, 1902.

The object of the inventor is to develop electric energy from gas. The inventor describes a series of apparatus, the first ones being adapted for the utilization of illuminating gas, while several types are shown which use the gaseous products of combustion from a fire, and one in which a coal gas retort is placed in close proximity to the furnace. The simplest form of apparatus consists essentially of a cylindrical vessel of cast-iron, which flares out at what in the shape of a funnel at its upper end. It is suspended over a gasburner and filled with

molten sodium or potassium hydrate. The latter is maintained at a temperature of something like 400° F. A hollow chamber is suspended into the electrolyte, resting on insulating brackets. It is composed of porous carbon, and its interior communicates with the supply of gas. Close to the wall of the iron vessel a tube reaches nearly to the bottom of the electrolyte, for the purpose of introducing air into the electrolyte. The carbon chamber is of positive and the iron pot of negative polarity. When fuel gas is forced into the porous chamber, the author believes that it percolates through the porous walls, which are permeable to a gas, but not to a liquid. The carbon and hydrogen of the gas are believed to unite with the oxygen in the electrolyte or in the porous carbon wall. A production or development of electricity follows and will continue as long as the gas is supplied to one side of the porous carbon chamber and oxygen to the electrolyte on the other side. The porous carbon electrode which the inventor uses at the present time is of carbon, manufactured in the electric furnace, and had not shown any deterioration after twenty-one days of continuous usage. The inventor is unable to give the exact amount of gas consumed for each electrical unit developed, but is convinced that the quantity of gas fuel consumed is not greater than would be required for developing a similar amount of energy under a steam boiler and transforming the energy into electricity by means of an engine and dynamo.

*Gas Battery.* J. H. Reid, Newark, N. J. Patent 736,017, August 11, 1903. Application filed December 20, 1902.

The battery is illustrated in the adjoining figure. A casing of preferably cast metal 1 is filled with an electrolyte of hydrate of sodium or potassium at a temperature of 392° F. The

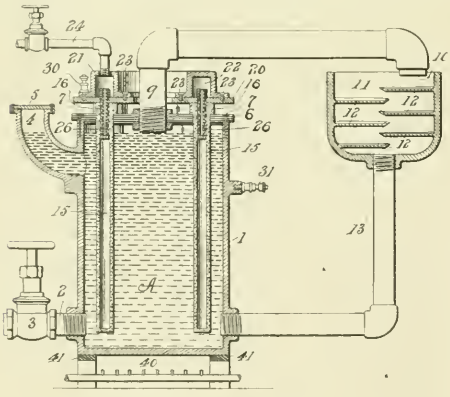



FIG. 5.—GAS BATTERY.

electrolyte is kept molten by means of a gas burner 40. Supported by an insulating cover 6, a number of porous carbon tubes 15, closed at the bottom, are suspended in the electrolyte. A collar 16 near the top of each tube makes a close joint with the cover 6. The tubes communicate with the gas supply through pipe 24 and the annular cap 21, and its channel 22. When the electrolyte, which contains a considerable amount of oxygen, is heated to the proper temperature, and it is desired to develop electrical energy, a fuel gas is introduced under pressure into the annular chamber 22. The gas is driven down into the porous tubes 15 and percolates through them. The electrolyte immediately begins to froth, and a portion of it is driven through pipe 9 into the funnel 11, being in its passage exposed to the air. It runs over the baffle-plates 12, and returns through pipe 13. A development of electrical energy follows, and can be obtained by making connections at 30 and 31. Replenishing of the electrolyte takes place through opening 4.

*Process of Treating Animal Hides or Skins.* G. D. Burton, Boston. Patent 739,825, September 29, 1903. Application filed November 8, 1898.

The inventor uses a rectangular vat, with the positive electrode at one end and the negative electrode at the other end of the vat. A screen of perforated wood or other insulating material is arranged in front of the electrodes. Rods run longitudinally through the tank from one screen to the other, below the level of the solution. The hides to be tanned are hung over them with their hair sides outward. Air is blown into the vat for circulation purposes. A current of from six to five hundred volts, and from five to five hundred amperes is said to be passed, depending on the size of tank, quantity of solution and number of hides. Electrolytic treatment for thirty minutes in the unhairing solution suffices in some cases. The skins are then drenched, and returned to the tank, which is then filled with a tanning solution. They are then again subjected to electrolysis. The best results are stated to have been obtained with a lead plate serving as anode and a copper cathode.

*Apparatus for Treating Gases.* H. Pauling, Brandau, Austria Hungary. Patent 739,920, September 29, 1903. Application filed April 2, 1902.

The specification describes an apparatus principally designed for the nitrification of atmospheric air. The principle of the apparatus is shown in the accompanying figure. The leading idea has been to act upon all parts of a given volume

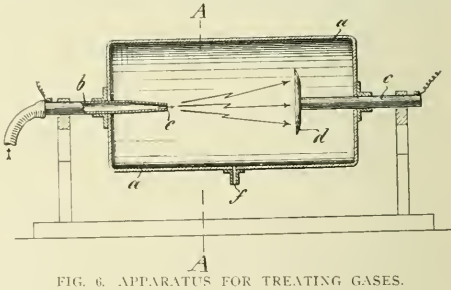



FIG. 6. APPARATUS FOR TREATING GASES.

of gas, instead of only on a small fraction of it at a time, as would be the case between ordinary electrodes. The apparatus consists of a cylinder a, in which the two electrodes b and c are mounted axially and insulated from the cylinder. The electrodes are tubular and connected with the poles of an induction coil. The positive electrode b terminates in a nozzle, while the negative electrode c carries a disc d. The gas to be treated is blown through b, and as the jumping of the spark takes place in the shape of a cone, the greater part of the gas current coincides with the spark path. The gases which have been subjected to treatment are sucked out of the cylinder a by means of pipe e, and passed on for further treatment. The gases to be treated can be subjected to the treatment in a more or less cooled or heated state, and under normal, increased or reduced pressure.

*Apparatus for Treating Gases.* H. Pauling, Brandau. Patent 739,921, September 29, 1903. Application filed April 2, 1902.

This apparatus is intended for the same purpose as the preceding one. The construction, however, is different, in so far as it has been the aim of the inventor to produce a sparking surface drawn out in band shape. He accomplishes this by mounting a wire in the form of a spiral, on the surface of a rotating cylinder of insulating material. The wire is connected to one pole of an induction coil, while a straight bar, parallel to the cylinder, serves as the other pole. If the speed of rotation of the cylinder is sufficiently great, a continuous spark-band is produced between the wire on the cylinder and the bar. A set of nozzles delivers the air right between the

bar and the cylinder. The apparatus is enclosed in a suitable casing, and, like the preceding one, can be adapted to varying degrees of temperature and pressure.

## CURRENT NOTES.

MADISON LOCAL SECTION OF THE AMERICAN ELECTROCHEMICAL SOCIETY.—The first local section of the American Electrochemical Society has been organized at Madison, Wis., with a dozen members. On account of the interest shown in this movement, it is expected that the membership of this section will considerably increase during the next months.

NEW YORK LOCAL SECTION OF THE AMERICAN ELECTROCHEMICAL SOCIETY.—The executive committee of this section will consist of Messrs. C. A. Doremus, chairman; Alois von Isakovics, secretary; C. O. Mailloux, W. Asa McCoy, and E. F. Roeber. A meeting of the executive committee is called for November 30, and the first meeting of the section will be held shortly afterwards.

LEHIGH VALLEY SECTION OF THE AMERICAN CHEMICAL SOCIETY.—We are informed by the secretary, Mr. W. S. Landis, that the Lehigh Valley section of the American Chemical Society met in the lecture room of Gayley Laboratory, at Lafayette College, Easton, on November 18, Prof. J. W. Richards presiding. The officers elected for the ensuing year are Mr. Porter W. Shimer, of Easton, chairman; Mr. Walter S. Landis, of Lehigh University, secretary, and Mr. Richard K. Meade, of Easton, representative of the section on the Council of the Society. The papers read and discussed were as follows: Compressive Strength of Cement, by Prof. Mansfield Merriman; on cement tests, by Mr. Ernest B. McCready; fuel efficiency of the rotary kiln, by Prof. J. W. Richards; the fallacy of the tests ordinarily applied to Portland cement, by Mr. Richard K. Meade; geology of the cement belt in Lehigh and Northampton Counties, Penn., by Prof. F. B. Peck. The meeting was one of the most successful ever held by the section, the cement industries of the valley being very fully represented.

RHODIN PROCESS.—The receiver of the American Alkali Co., which owns and formerly had in operation the Rhodin process for making caustic alkali and bleach, recently called on the holders of preferred stock for an additional assessment—the preferred stock having paid 20 per cent at the time of the organization of the company. The additional assessment was resisted by several of the stockholders, among them Messrs. Salom and Morris of Philadelphia, and suit was brought by the company against Messrs. Salom and Morris, and others. The defence of the latter was that the original representations under which the subscriptions were obtained, were misleading, as far as the statements in relation to paying the Commercial Development Co. certain sums of money, and stock for the patents, and so far as the basic nature of the patents themselves were concerned. The case was recently tried in Philadelphia and the jury decided in favor of the defendants.

CATHODIC FORMATION OF SODIUM ALLOYS.—In his American Electrochemical Society paper on the "Formation of Metallic Dust From Cathodes" (ELECTROCHEMICAL INDUSTRY, October, 1902, p. 60), Prof. F. HABER showed an experiment in which potassium hydroxide is electrolysed with a lead cathode, at a sufficiently high cathodic current density a black cloud was seen to go off from the cathode, the cloud consisting of fine particles of lead. The explanation of this phenomenon, given by Prof. Haber, is that primarily an alloy of lead and potassium is formed which cannot exist in contact with the solution and decomposes the water. If such an alloy is prepared chemically and brought in contact with water, the same phenomenon is observed. The cathodic formation of an alloy seemed to be indeed a very general phenomenon (see KAHLENBERG, ELECTROCHEMICAL INDUSTRY, February, 1903, p. 201). The phenomenon is discussed by Dr. M. SACK, who gives the results of his investigation in a pamphlet on the formation of sodium alloys and their importance for the cathodic polarization (thesis, Technische Hochschule, Karlsruhe, 1903). The author studied the potentials of the sodium alloys of lead and tin and investigated whether the polarization phenomena at lead and tin in sodium hydroxide show simple relations to the potentials of these alloys. Such relations have, indeed, been found. The polarization phenomena are explained by the intermediate formation of the same sodium alloys which can be prepared chemically by fusing sodium and lead or tin together. The roughening of the surface is a preliminary step preceding the formation of dust from the cathode. Zinc and platinum are materials which, when used as cathodes, do not give up dust, but their surface becomes roughened. On the other hand, when lead and tin cathodes are used in sodium hydroxide, both a roughening of the surface and an evolution of dust are observed. The roughening of the cathode surface, which is combined with a strong evolution of hydrogen, takes place at lead at a cathodic potential of about 0.7 volt, at tin at 0.4 volt, against hydrogen in the same solution as zero. The evolution of metallic dust occurs at a lead cathode at a cathodic potential of about 1.5 volts, at tin at about 1.4 volts. The roughening of the surface of platinum and of lead is much greater when an acid is used as electrolyte than an alkali. This is explained as due to the fact that the discharged sodium cannot so easily enter into the pores of the cathodic metal, as the more mobile hydrogen. This shows that the hydrogen development from sodium hydroxide at these cathodes is essentially of secondary character.

# Book Reviews.

BIBLIOGRAPHIE DER METALLLEGIERUNGEN. By Dr. M. Sack. Hamburg and Leipzig: Leopold Voss; 78 pages. Price, 70 cents.

This is a reprint in book form of the paper already referred to on page 429 of our August issue. As noticed there, this is a list of the literature on metallic alloys, which has evidently been prepared with the greatest care and appears to be complete. Eight hundred and eighty articles and papers are referred to, the arrangement being first alphabetically, according to the names of the authors. The name of the author, the title of the article, the journals in which it first appeared and in which it was afterwards abstracted, are given, together with a brief and concise statement of the special alloys which are dealt with in the article. A second list is arranged alphabetically according to the metals contained in the alloys. In view of the increasing industrial importance of alloys, the compilation of this list, which has certainly required an enormous amount of work, is highly creditable.

DIE HERSTELLUNG DER ACCUMULATOREN, EIN LEITFADEN. By E. Gruenwald, Halle: W. Knapp. Third edition. Price $1.00.

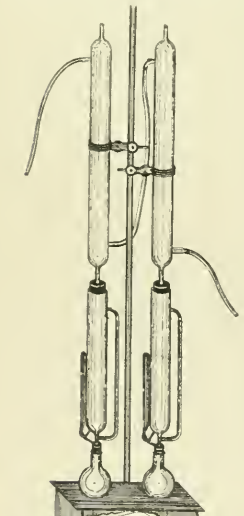
This small book is intended to be a pocket book for the German storage battery engineer, and its appearance in the third edition shows that it has found many friends. It contains, indeed, in a concentrated form almost everything that is necessary for an introduction into this branch of engineering, and answers many questions that occur to the storage battery manufacturer. It is so complete as to give even the German laws for storage battery manufacturing plants, and the safety regulations of the German Association of Electrical Engineers. It may be acknowledged that the writer has taken peculiar pains to take advantage of all modern developments, both theoretical and practical, as far as possible

Radium, and Other Radio-Active Substances, Polonium, Actinium and Thorium. With a Consideration of Phosphorescent and Fluorescent Substances, the Properties and Applications of Selenium, and the Treatment of Disease by the Ultraviolet Light. By William J. Hammer. New York: D. Van Nostrand Co. Price, $1.00.

We are glad to note that the splendid and highly elaborate lecture delivered by Mr. William J. Hammer last spring, before a joint meeting of the American Institute of Electrical Engineers and the American Electrochemical Society, has now appeared in book form. It is the only book on the market which gives exact information on this subject, and is at the same time written in a clear and lucid style so that it should appeal not only to physicists and chemists, but to every educated man. The book should have a large sale.

Modern Electrolytic Copper Refining. By Titus Ulke, E. M., New York: John Wiley & Sons. Price $3.00.

The task which confronts the reviewer of this book is a somewhat hard one. There is much to be praised and something to be deprecated. The chief fault of Mr. Ulke's writings is he draws inferences at times when it would be a safer and more conservative course to simply state what he knows to be a fact. This reminds the reviewer of a story of a Swede who was about to return to the old country after a long sojourn in the land of the free and the home of the brave. Reaching the dock at 10:01 A. M., when the vessel was scheduled to sail at 10:00 A. M., he saw a narrow strip of void between the vessel and the dock. Crying for advice, he saw a friend hanging over the rail on the departing boat. This man answered his supplications by the exhortation, "yump, yump, Lars, you can do it in two yumps."



ETHER EXTRACTION

Mr. Titus Ulke has unfortunately tried to take two "yumps" where it would have been safer to have accepted the inevitable.

The point brought out in his preface that it was impossible to secure accurate descriptions of certain American refining plants is of course true. This is a perfectly natural course for the managers of these refineries to take, for the several refineries are at times engaged in strenuous competition to secure contracts for copper matte or bullion, and any information which one concern has and which others have not is a distinct commercial asset to the more fortunate concern.

The book, as books of technical matters go, is a very ably written and fairly complete resumé of the history of the development of electrolytic copper refining and is valuable for the brief account of the various metallurgical plants, which, considering the difficulties undergone in preparing the same, is quite accurate.

In Chapter I. all the principal problems involved in electrolytic copper refining are discussed in general. This chapter contains historical and statistical data, a comparison of the series and multiple system of cells, an outline of the chemistry and physics of refining, and a discussion of the treatment and purification of foul solutions.

In Chapter II. descriptions and views of electric copper-refining works in the United States, Great Britain, Germany, Austria-Hungary, France and Russia are given.

Chapter III. contains an estimate of the cost of an electrolytic copper and nickel refinery, with general plan and detail drawings. In an appendix a chronological list of patents, books and special articles on electrolytic copper-refining methods and apparatus is given.

# Correspondence.

## ETHER EXTRACTION BY ELECTRICAL HEAT.

To the Editor of Electrochemical Industry:

Sir—An apparatus like the one illustrated here, has been in use nearly two years, and has been found to be a very satisfactory means of furnishing heat in making extractions with ether and other solvents of low boiling points. It also works to a nicety in evaporating from platinum dishes in making ash determinations, etc.

The bath shown here is 7 inches long, by 3 inches wide, constructed of copper and lined with corrugated asbestos 1-16 inch thick.

The apparatus is heated with one 32-candle-power lamp, on a 220-volt direct current, which gives a temperature of 115° centigrade in ten minutes after turning on the light.

A bath of the size mentioned here will operate two sets of extraction apparatus.

H. M. Burr.

Brooklyn, N. Y.

## DRYERS.

In the adjoining diagrams we illustrate the latest types of dryers made by the Jeffrey Manufacturing Co., of Columbus, Ohio. Fig. 1 shows a dryer operated by live or exhaust steam, for drying pulverized or granular products, ores, chemicals, etc. The dryer consists of six steam-jacketed tubes, 12-inch inside diameter, each tube being provided with a 10-inch diameter extra heavy spiral conveyer. The conveyer being smaller than the tube, there is sufficient space for the moisture. It is provided with mixing paddles or lifting blades, which keep the material thoroughly agitated and all particles exposed to the surface of the steam jacket. The construction is clearly shown in the illustration.

The tubes really have two jackets, one for the steam and one for hot air. The steam occupies the space next to the conveyer. Outside of the steam jacket is located a hot air jacket, made of galvanized iron.

These six tubes are riveted to cast-iron nozzles or connecting spouts, which form the bearings for the screw conveyer. A steam dust or connection is cast into these spouts to allow the free circulation of steam from one tube to the other, forming a continuous flow of steam from the inlet of the upper tube to the drip pipe of the lower tube. The drip pipe allows the condensed steam to pass off. Each tube is provided with a pipe connection to the exhaust fan for drawing off the moisture. Instead of drawing cold air through the tube, hot air is introduced, the air being heated by passing through the air holes of the hot air jacket and through this jacket into the tubes, coming in direct contact with the material which is being carried through the same by the spiral conveyers. The hot air, after having passed through the tubes, passes into the exhaust pipe with the moisture that it has collected, and is thrown off by the suction fan. The air with the moisture is drawn through the tubes in the opposite direction from that of the material. By this operation the moisture is never drawn over that portion of the material from which the moisture has already been extracted. The same principle applies to each tube.

The steam tubes of the dryer are sufficiently strong to sustain a pressure of fifty pounds. At ten revolutions of the spiral

conveyers the capacity is approximately 250 cubic feet of material per hour. Of course, the capacity depends largely upon the nature of the material and the amount of moisture it contains. The speed of the fan should be about 800 revolutions per minute.

There are gate-valves in the suction pipes which draw away the moisture. These valves can be so adjusted that, as the material dries and becomes lighter, the amount of suction area can be cut off to suit.

The driving arrangement consists of cone pulleys on the countershaft, also a small pinion, all attached to the drive frame, so that the speed of the spiral conveyers can be changed to 6, 8 or 10 revolutions, as the nature of the material may require. The spiral conveyers in the tubes are connected by means of spur gears.

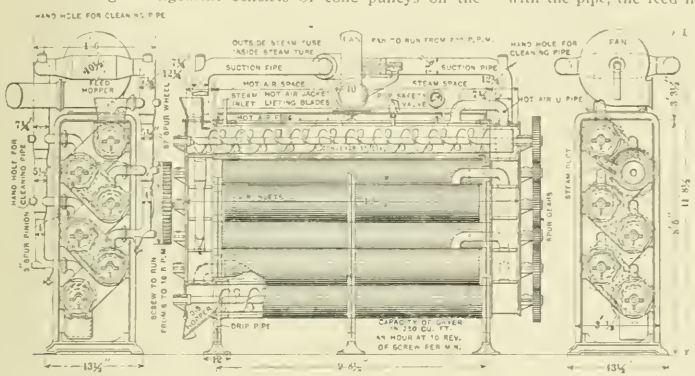



FIG. 1. STEAM DRYER.

The capacity stated above is based on ten revolutions, as mentioned before. Material containing a large percentage of moisture has to run through a longer period of time, and, consequently, the speed of the conveyers will have to be reduced. Where the material contains but little moisture, the speed of the conveyer can be increased.

Fig. 2 shows a rotary dryer, consisting principally of a steel drum or cylinder, 4 feet in diameter, 18 feet long, constructed of 5-16-inch steel plates, being supported by short shafts extending into each end of the shell and running in bearings located outside of the brick work. The cylinder is encased in brick work the entire length, provided at each end with cast-iron plates, having circular openings that fit neatly around its ends to prevent the escape of the hot air from the furnace.

At the receiving end of the dryer and below the driving gears, the furnace is located, having 20 square feet of grate surface, two fire doors and two ash doors. Above the grate surface and extending back to about two-thirds the length of the cylinder, is a brick arch which conducts the heat to the lower end of the cylinder. In this arch two cast-iron valves or dampers are placed under the cylinder to distribute a more uniform heat over the entire length; these valves or dampers can be opened and closed to regulate the heat according to the condition of the fire. Peep-holes are arranged in the side of the furnace wall to allow the operator to see just how much to open or close the above valves. The heat and smoke from the furnace envelop the entire area of the cylinder and pass up into the stack, which is placed on the top brick arch near the receiving end.

An exhaust fan is placed at the receiving end of the dryer and connected to the inside of the cylinder, and also the stack. A circular steel casing is placed at the receiving end of the cylinder, fitting closely to the same and connecting to the fan with the pipe, the feed hopper or chute which carries the material to the cylinder passing through this circular casing.

The cylinder is provided with four internal angle-iron lifting blades, so that at every revolution the material is lifted four times, thus keeping it well scattered, allowing the free escape of all moisture, which latter is drawn off by the suction fan into the stack. This fan serves as a force draft for the furnace.

In the smoke stack, and also in the suction pipe connecting with the fan, valves are placed for the purpose of controlling the vapor suction and the furnace draft, these valves being under the convenient control of the operator.

A cone-shape receiving hopper is placed under the elbow of the exhaust pipe leading from fan to stack for the purpose of catching all fine or light material that may be lifted into the same by the fan, and by means of this hopper the material so collected can be drawn off when necessary. Should the collection of this material be considerable, it is evident that the fan is running too fast and should be slowed down until the desired results are obtained. The capacity of this dryer will depend upon the nature of the material and the amount of moisture it contains. If the material contains from 6 to 8 per cent of moisture, the capacity is estimated at from 8 to 10 tons per hour. With more or less moisture the capacity will vary proportionately.

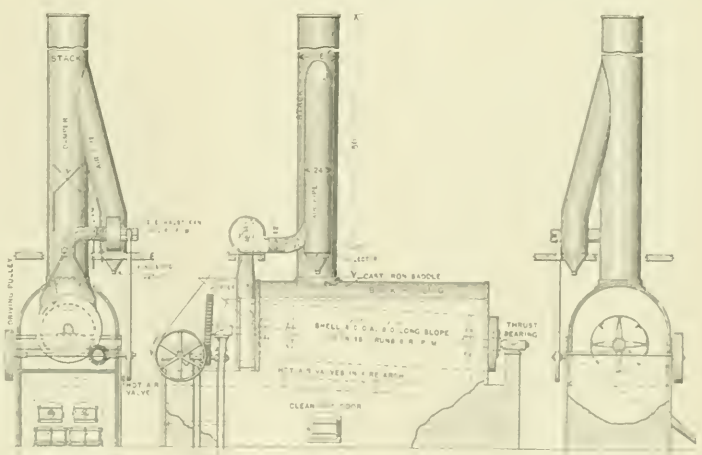



FIG. 2. ROTARY DRYER.

The dryer is so arranged that no smoke or gas from the furnace can come in contact with the material, thus preventing

discoloration. On this account, any kind of fuel can be used, bituminous, slack, run of mine or lump, also coke, gas, oil or wood, whichever may be the cheapest in the locality where the dryer is to be operated.

## MEASUREMENT OF HIGH TEMPERATURES.

Although the demand for a practical apparatus with which high temperatures can be measured is very large, science could meet this demand up to a short time ago only by instruments based on empirical rules. It is evident that the accuracy of measuring high temperatures was therefore somewhat limited. The well-known Le Chatelier thermo-element does not reach the limit of high temperatures. The color of glowing bodies was, therefore, mostly made use of for the approximate determination of their temperature.

As early as February, 1900, a description of a new method for measuring high temperatures was published by Dr. H. Wanner which was based on a new basis; namely, on a law which had first been theoretically deducted, and the correctness of which had been afterwards proven by extended experiments. He showed that by this new method the same value for the temperature of the electric arc light could be obtained as had been determined previously by other scientists by much more complicated methods. The new method showed a possibility of measuring temperatures up to 4000° C. and above. The following information is taken from a lecture of Dr. Wanner.

The law, as established experimentally, permits at least for a certain group of glowing bodies (the so-called theoretically "black bodies") the measurement up to the highest temperatures. When a compact body is heated, the rays emanating from the same may be observed by the human eye, and the body's color will change with rising temperature from dark red to light red, to yellow and to bright white. This means that at first mainly red rays are observed, to which, at the higher temperatures the other spectrum colors, orange, yellow, etc., are added, until the rays appear white. In analyzing the rays by a prism it is found that with the rise of temperature some single color, for instance, red, undergoes a rise in intensity which can be measured progressively with a specially constructed photometer. If we know the law for the mutual relation between the determining factors (the temperature, the light intensity of the single color, and its wave length) we are enabled to measure high temperatures by the photometric measurement of the light intensity of a certain color.

The apparatus to be applied is, therefore, a photometer, containing at the same time a prism to separate a single color. A spectrum is produced in the ordinary manner with the aid of a slit, lenses and a prism, from which, by means of a diaphragm, the light of a certain wave length is separated, and the measurement of the light intensity is made by polarization. To that part of the apparatus which faces the radiation to be examined, a small incandescent lamp is attached, the light of which is used for comparing the intensity of the light to be measured.

On looking through the apparatus one observes the circular field of vision, divided into two halves (like in a one-half shade sugar-testing polariscope), one of which is illuminated by the small incandescent lamp and the other by the light of the glowing body being examined. Both halves of the field show red color. On turning the eye piece containing the Nicol prism, both halves of the field vision can be easily brought to equal intensity, and on a circular scale the number of degrees are read. The actual temperature is found from a table which accompanies each instrument. The temperatures given on the table have been calculated by means of the law mentioned before

The method may be considered from the following point of view. The electric comparison lamp is emitting rays of a known temperature with which the unknown temperature is being compared. The entire procedure is so simple that it can be readily learned by any foreman or intelligent workman within a short time. The whole apparatus is 30 cm. long (12 inches), built like a telescope and can be easily handled without a support. It does not matter how great the distance is from which the measurements are taken, if only the field of vision is properly illuminated by the light emanating from the body to be examined.

The exactness of this new method depends solely on the accuracy of the observer and on the degree to which the body under test approximates what is called in the theory of radiation a "black body." Errors due to lack of experience of the observer are practically eliminated, for various parties, which have been asked to take measurements, and which used this apparatus for the first time, have obtained the same correct results. The nearest approximation to the theoretical "black body" are the insides of closed furnaces, as muffle furnaces, etc., the glow of which is observed through a small opening, which, however, must not be covered by glass or mica during the measurement. The measured temperature is equal to the real one within a few degrees.

By actual experiments Dr. Wanner obtained for blast furnace slag a temperature of 1321° C., for outpouring iron 1384 C., for slag pouring from the converter 1700° C. The temperature of the converter gases seemed to remain below 1500° C., however, the radiation of the flame causes a rise of temprature as decarburation, etc., progresses. The falling of the temperature, during the addition of scrap can be measured progressively, while the absolute temperatures cannot be obtained on account of the constant changeable transparency of the flame The temperature of flowing steel can only be measured by looking directly upon the same.

The chief advantages of this new apparatus, whose sole agents for the U. S. A. are Messrs. Eimer & Amend, of New York City, are reliability (because its indications are based on a law of nature, resting on the principles of thermodynamics, and not on an empirical rule), accuracy, handiness (it may be used with or without support), portability, and quick adjustment (requiring in practice but a few seconds). The instrument may be adjusted at the start to any desired temperature, thus showing exactly when this temperature is reached. Another special advantage of the apparatus is that it can be directed upon any visible part of the furnace in order to compare the temperature at different places in the furnace. It should be of the greatest value for iron and steel furnace men, for operators of electric furnaces, and, in fact, for everybody who wishes to measure exactly a high temperature.

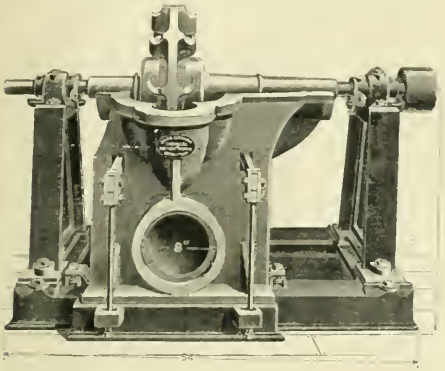
## STONEWARE EXHAUST FAN

The accompanying illustrations show a stoneware exhaust fan, made by the Chas. Graham Chemical Pottery Works, of Brooklyn, N. Y. The primary purpose of these stoneware exhausters is to remove objectionable acid gases and to direct such gases through regenerative apparatus.

Wherever large chemical operations are carried on with acids, fumes are generated to an extent which seriously affects the health of the men. For instance, in the manufacturing of smokeless powder, nitric acid fumes are generated to such an extent as to make it almost impossible for men to work. By installing stoneware exhaust fans, the nitric acid vapors are rapidly removed and the conditions under which the men work are very greatly improved. At the same time a saving can be accomplished by the use of these fans, since the acid gases, instead of being allowed to escape, may be driven through the fan into stoneware towers, where they are regenerated for further use. These fans are generally useful for removing poisonous gases developed in electrochemical works, denitrating plants and in chloride of lime factories.

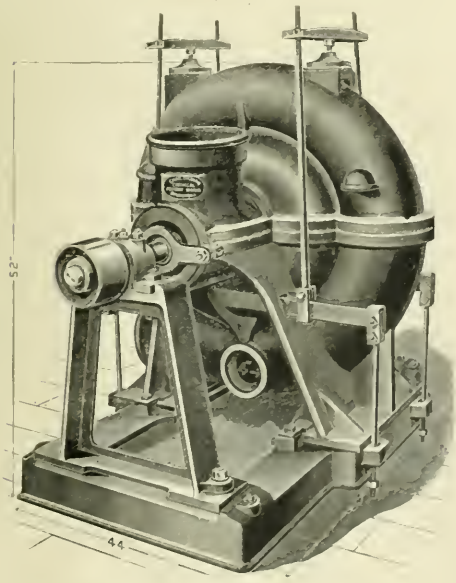
The exhaust fans of the Chas. Graham Chemical Pottery Works are made of vitrified stoneware of such a character

that it cannot be affected by the action of acid vapors. The construction of the fan is such that acid fumes cannot possibly come in contact with anything but the earthenware itself. The iron shaft which actuates the fan inside of the stoneware shell is covered in a thorough manner with earthenware sleeves, so that the acid gases have no chance to come in contact with the iron shaft. In this way the shaft is not only protected from the corrosive action of acid, but the purity of such acid as may be condensed in the fan is insured.



Cross View

STONEWARE EXHAUST FAN.




Front View

STONEWARE EXHAUST FAN.

These fans are operated at a speed of 1200 revolutions per minute. Before shipping, the fan is set up in the factory and is tested thoroughly in actual operation. This precaution is very important, as at the high speed of operation a slight defect in the fan would be a serious matter. These exhaust fans are made to be operated with either steam power or electric power.

The weight of the fan disc and sleeves is 90 lbs., that of the inlet piece 40 lbs., that of the top shell 190 lbs., and that of the bottom shell 355 lbs., so that all earthenware parts together weigh 675 lbs. Since the iron parts, including the base-plate, weigh 900 lbs., the total weight of the fan is 1575 lbs. The fan is shipped in assembled condition ready for operation. It is packed carefully in heavy timber frame, to make sure of its safe arrival at any destination. The total shipping weight is 1800 lbs.

The exhaust of this fan is at the rate of 2600 cubic ft. per minute. The diameter of section and exit opening is 8 ins., the diameter of the fan is 24 ins., the height of the whole apparatus is 52 ins., and the diameter of the operating pulley is 6½ ins.

Fig. 1 is a cross view and Fig. 2 a front view of the fan.

## PERSONAL.

MR. BENJAMIN MAGNUS, superintendent of the Electrolytic Refinery and Silver Mill of the Anaconda Copper Mining Co., will shortly leave Montana, and expects to locate in the East.

MESSRS. LITTLE & WALKER, chemical experts and engineers, of Boston, Mass., announce the removal of their offices to 93 Broad Street, where they have greatly extended their facilities for handling all matters relating to technical chemistry.

## INDUSTRIAL NOTES

STORAGE BATTERIES.—We have received from the Columbus Storage Battery Co., of Columbus, Ohio, their third annual catalogue of storage batteries. On the first 14 pages, an elementary discussion of the use and care of storage batteries is given; then follow some notes on features of the construction of the type of cell made by this company. The catalogue is concluded by a price list.

CHEMICAL STONEWARE.—We have received from Messrs. Richard C. Remmey & Son, Philadelphia, Pa., their catalogue of chemical stoneware for manufacturing chemists. It is profusely illustrated, some of the subjects dealt with being stoneware cooling worms, chemical refining pots, various vessels and apparatus in close-grained mass, coolers or precipitating pots, stoneware corks, stills, evaporating dishes, connecting pipes and receivers, perforated pans for methylic anilin, apparatus for purifying and bleaching crude nitric acid, condensing towers, pipes, glover towers, muriatic acid towers, acid pumps, etc.

CALORIMETERS AND PYROMETERS.—We have received from Messrs. Elwer & Amend, of New York City, their latest catalogue of calorimeters and pyrometers and other apparatus for measuring temperatures and determining the heating value of combustible gases, liquids and solids. The catalogue contains an extended illustrated description of the Junkers gas calorimeter; the Parr standard calorimeter for determining the heat units in bituminous and anthracite coal, lignites, coke, petroleum, etc.; various other types of calorimeters and pyrometers, especially the new platinum rhodium pyrometer (being a thermo cell). Among the other pyrometers briefly noticed there is the interesting optical pyrometer of Wanner, a description of which will be found on another page of this issue. The catalogue also contains a description of apparatus for rapid gas analysis by Elliott; sulphur apparatus in the improved form of Elliott; Weber's opal glass for photometer; standard photometer with accessories and Lummer-Brodhun prisms (the type used by the German Reichsanstalt) and a great many other apparatus for laboratory work. Especially apparatus for gas analysis are described and illustrated in various forms. Other subjects dealt with in the catalogue are acetylene gas generators, oil-testing apparatus, gasoline gas generators, hot-

[illegible] make up and the illustrations [illegible] very neat.

Pump Manufacturing Plant.—An extensive pump manufacturing plant, which is stated to be the largest in this country, and probably in the world, is now under construction, at Harrison, N. J. It is to be occupied by the firm of Henry R. Worthington, who employ about 3,000 men in their present works at South Brooklyn, L. I., and Elizabethport, N. J. The new plant at Harrison will accommodate from 4,000 to 5,000 men, and will cost in the neighborhood of two million dollars. It consists of a main machine shop with side galleries over 1,000 feet long, an erecting shop 592 feet long, and of the same section as the machine shop, and a high erecting shop 210 feet in length, and four galleries in height in the side bays connecting the two shops. The main foundry is 600 feet in length, and there is also a special foundry for small work, 410 feet in length, with a building 200 by 60 feet in size for cleaning castings connecting the two. The pattern building is four stories high and 550 feet long, and is divided by fire walls into four sections. The north section will be used for offices and drafting rooms; the adjoining section for the pattern shop and the balance of the structure for pattern storage. The power house, which will be equipped with the most modern boilers, engines and generators, is a building 172 by 102 feet. Electric power distribution is to be employed throughout. All will be connected by a complete system of railroad tracks entering the ends of the buildings and placing the works in direct communication with the Delaware, Lackawanna & Western, the Erie and the Pennsylvania Railroad systems. The new plant will be devoted entirely to the manufacture of water works machinery, water meters, cooling towers, condensers, feed-water heaters, centrifugal pumps and steam pumps of all kinds.

## DIGEST OF U. S. PATENTS

Prior to July, 1902.

*Compiled by Byrnes & Townsend,*
*Patent Lawyers,*
*National Union Building, Washington, D. C.*

Chemicals.

284,862. September 11, 1883. Mark H. Lackersteen, Chicago, Ill.

Converts neutral fats or oils into fatty acids and glycerine. First method: Melts the fat or oil, adds 12 per cent or more of water and intimately mixes to produce an emulsion, which is electrolyzed. The nascent oxygen and hydrogen from the water liberate the glycerine, which settles to the bottom and is drawn off. The cell is of copper or iron lined with copper, and may constitute one of the electrodes, the other being centrally placed in the vessel. Or the emulsion may be forced through a tube which contains, or portions of which constitute, the electrodes. Second method: Supports the melted fat or oil on water and electrolyzes the water only. The hydrogen and oxygen rise through the fat and effect the chemical reactions. In this method, the charge is kept in agitation by stirrer-arms and by steam blown upwards from a coil in the water above the electrodes. The steam jets the water upwards into the fat and maintains the emulsion at a temperature from 250° to 350° F. The conversion is accelerated by the pressure produced in the cell by the liberated gases, this pressure being controlled by breaking the electric circuit as required. The electrodes here consist of a network of copper wire. The fat may first be cleaned by carrying out the second method with a small amount of injected steam. When the depuration is complete, the volume of steam is increased to flow the water upwards into the fat and form the emulsion. The vessel is preferably filled seven-eighths full of water and fat: one-eighth of water at the bottom and six-eighths of fat thereon.

322,940. July 28, 1885. Theodor Kempf, Berlin, Germany.

Produces iodoform, bromoform and chloroform by electrolyzing a heated, aqueous solution of the corresponding alkali or alkaline earth haloid, and alcohol, aldehyde or acetone. E. G. Electrolyzes a solution of 50 kg. of potassium iodide and 30 kg. of 96 per cent alcohol in 300 kg. of water, continuously injecting carbon dioxide and employing a current of 60 amperes. The iodoform separates as a crystalline powder. To obtain large crystals, the potassium iodide is dissolved in 20 per cent of alcohol. Bromoform or chloroform are produced from similar solutions without the injection of carbon dioxide, being distilled from the cell as produced.

326,057. September 22, 1885. Theodor Kempf, Berlin, Germany.

Produces permanganates by electrolyzing the corresponding manganate. Preferably employs a diaphragm cell, the base, for example, potassium hydroxide, being liberated in the cathode compartment.

339,727. April 13, 1886. Elias C. Atkins, Indianapolis, Indiana.

Passes electricity through the contents of a soap kettle to accelerate the production of soap. The kettle is steam-jacketed and contains a vertical, annular, central partition, spaced away from the bottom, in which is mounted a screw-shaped stirrer. This partition may constitute one electrode, the other consisting of three carbon plates set in a wooden frame. To treat a charge of 100 gallons, the potential difference is maintained at 50 volts for thirty minutes.

353,566. November 30, 1886. Mark H. Lackersteen, Chicago, Ill.

Modifies the process of his patent 284,862 to produce soap and glycerine. Electrolyzes an emulsion of the neutral fat or oil with an alkali, treated with dilute acid, or an emulsion with a solution of an alkali salt. E. G. Electrolyzes an emulsion of a melted fat and a saturated aqueous sodium chloride solution, in a diaphragm cell, the glycerine being set free at the anode and the alkaline base at the cathode where it combines with the fatty acids. The chlorine escapes from the anode compartment.

393,578. November 27, 1888. Leonard Paget, New York, N. Y.

Produces merchantable products by the action of a voltaic cell. E. G. Generates chlorine by the action of sulphuric acid on bleaching-powder and conducts it into a voltaic cell having an anode of zinc or iron, a cathode of lead coated with lead peroxide or a lead salt, and an electrolyte of water containing calcium carbonate in suspension. The chlorine maintains peroxidation of the lead, giving an e. m. f., with zinc, of 2.3 volts. The calcium carbonate in suspension is provided by dissolving calcium hydroxide or a calcium salt in the water and injecting carbon dioxide. The zinc or iron chloride produced by the action of the cell is recovered. The zinc may be placed in a solution of caustic soda contained in a porous cell immersed in the water. The e. m. f. is here 2.7 volts and the useful by-product is sodium zincate. May replace the chlorine by hydrobromic acid gas, produced by the action of hydrogen sulphide on bromine water. The voltaic cell then has a carbon or platinum cathode and an electrolyte of dilute sulphuric acid. The zinc or iron bromide is recovered. The voltaic cell is preferably closed, the pressure developed by the gases when the cell is on open circuit retarding the evolution of gas, while the decreased pressure due to the absorption of gases when the cell is on closed circuit may be employed to effect an automatic in[illegible] of active material.

(*To be concluded.*)

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